# ANNUAL REPORT OF THE BOARD OF REGENTS OF

# THE SMITHSONIAN INSTITUTION

SHOWING THE

## OPERATIONS, EXPENDITURES, AND CONDITION OF THE INSTITUTION FOR THE YEAR ENDING JUNE 30

## 1930

26. 4. 1932.
:- 14,553.




(Publication 3077)

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1931

For sale by the Superintendent of Documents, Wsshington, D. C. - - - - - - Price $2.00 (cloth)

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# LETTER

FROM THE

# SECRETARY OF THE SMITHSONIAN INSTITUTION

SUBMITTING

## THE ANNUAL REPORT OF THE BOARD OF REGENTS OF THE INSTITUTION FOR THE YEAR ENDED JUNE 30, 1930

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SMITHSONIAN INSTITUTION,
*Washington, December 9, 1930.*

*To the Congress of the United States:*

In accordance with section 5593 of the Revised Statutes of the United States, I have the honor, in behalf of the Board of Regents, to submit to Congress the annual report of the operations, expenditures, and condition of the Smithsonian Institution for the year ended June 30, 1930. I have the honor to be,

Very respectfully, your obedient servant,

C. G. ABBOT, *Secretary.*

# CONTENTS


| | Page |
|---|---|
| List of officials | XI |
| The Smithsonian Institution | 1 |
| Outstanding events of the year | 1 |
| The establishment | 2 |
| The Board of Regents | 2 |
| Finances | 3 |
| Matters of general interest | 7 |
| Award of Langley Medal to Charles Matthews Manly and to Commander Richard Evelyn Byrd, United States Navy | 7 |
| Additions to the Natural History Building of the National Museum | 8 |
| Researches in European archives | 8 |
| Rocket experiments of Dr. R. H. Goddard | 9 |
| Low temperature researches | 11 |
| Division of Radiation and Organisms | 11 |
| Explorations and field work | 12 |
| Cooperative ethnological and archeological investigations | 13 |
| Publications | 14 |
| Smithsonian Scientific Series | 15 |
| Library | 15 |
| Governmentally supported branches | 16 |
| National Museum | 16 |
| National Gallery of Art | 18 |
| Freer Gallery of Art [1] | 18 |
| Bureau of American Ethnology | 19 |
| International Exchanges | 19 |
| National Zoological Park | 20 |
| Astrophysical Observatory [1] | 20 |
| International Catalogue of Scientific Literature | 21 |
| Necrology | 21 |
| Appendix 1. Report on the United States National Museum | 25 |
| 2. Report on the National Gallery of Art | 45 |
| 3. Report on the Freer Gallery of Art | 54 |
| 4. Report on the Bureau of American Ethnology | 61 |
| 5. Report on the International Exchange Service | 72 |
| 6. Report on the National Zoological Park | 84 |
| 7. Report on the Astrophyiscal Observatory | 103 |
| 8. Report on the Division of Radiation and Organisms | 115 |
| 9. Report on the International Catalogue of Scientific Literature | 123 |
| 10. Report on the library | 126 |
| 11. Report on publications | 141 |
| 12. List of subscribers to The James Smithson Memorial Edition, Smithsonian Scientific Series, since Nov. 15, 1929 | 147 |
| Report of the executive committee of the Board of Regents | 149 |
| Proceedings of the Board of Regents | 159 |


[1] In part governmentally supported.

GENERAL APPENDIX

Page
Beyond the red in the spectrum, by H. D. Babcock ..... 165
Growth in our knowledge of the sun, by Charles E. St. John ..... 177
The modern sun cult, by J. W. Sturmer ..... 191
The moon and radioactivity, by V. S. Forbes ..... 207
Modern concepts in physics and their relation to chemistry, by Irving Langmuir ..... 219
Waves and corpuscles in modern physics, by Louis de Broglie ..... 243
New researches on the effect of light waves on the growth of plants, by F. S. Brackett and Earl S. Johnston ..... 255
The Autogiro: Its characteristics and accomplishments, by Harold F. Pitcairn ..... 265
Ten years' gliding and soaring in Germany, by Prof. Dr. Walter Georgii ..... 273
The first rains and their geological significance, by Assar Hadding ..... 285
Weather and glaciation, by Chester A. Reeds ..... 295
Wild life protection: An urgent problem, by Ernest P. Walker ..... 327
The nesting habits of Wagler's Oropendola on Barro Colorado Island, by Frank M. Chapman ..... 347
The rise of applied entomology in the United States, by L. O. Howard ..... 387
Man and insects, by L. O. Howard ..... 395
The use of fish poisons in South America, by Ellsworth P. Killip and Albert C. Smith ..... 401
A rare parasitic food plant of the Southwest, by Frank A. Thackery and M. French Gilman ..... 409
The mechanism of organic evolution, by Charles B. Davenport ..... 417
Extra chromosomes, a source of variations in the Jimson weed, by Albert F. Blakeslee ..... 431
The age of the human race in the light of geology, by Stephen Richarz ..... 451
Elements of the culture of the circumpolar zone, by W. G. Bogoras ..... 465
The Tell en-Nasbeh Excavations of 1929—a preliminary report, by William Frederic Badé ..... 483
Recent progress in the field of Old World prehistory, by George Grant MacCurdy ..... 495
Ancient seating furniture in the collections of the United States National Museum, by Walter Hough ..... 511
Aspects of aboriginal decorative art in America based on specimens in the United States National Museum, by Herbert W. Krieger ..... 519
The acclimatization of the white race in the Tropics, by Robert De C. Ward ..... 557
The eighth wonder: The Holland Vehicular Tunnel, by Carl C. Gray and H. F. Hagen ..... 577
Jesse Walter Fewkes, by John R. Swanton and F. H. H. Roberts, jr ..... 609
George Perkins Merrill, by Charles Schuchert ..... 617

# LIST OF PLATES


Page

Beyond the red in the spectrum (Babcock):
Plates 1, 2 ..... 176

Knowledge of the sun (St. John):
Plates 1–7 ..... 190

Waves and corpuscles (De Broglie):
Plates 1, 2 ..... 254

Light and plant growth (Brackett and Johnston):
Plates 1–3 ..... 264

The autogiro (Pitcairn):
Plates 1–9 ..... 272

Gliding in Germany (Georgii):
Plates 1–16 ..... 276

Wild life protection (Walker):
Plates 1–4 ..... 346

Nesting habits of Oropendola (Chapman):
Plates 1–8 ..... 372

Fish poisons (Killip and Smith):
Plates 1–5 ..... 408

A parasitic plant (Thackery and Gilman):
Plates 1–9 ..... 416

Organic evolution (Davenport):
Plate 1 ..... 421

Extra chromosomes (Blakeslee):
Plates 1–13 ..... 436

Age of the human race (Richarz):
Plates 1–3 ..... 464

Tell en-Nasbeh excavations (Badé):
Plates 1–8 ..... 494

Old World prehistory (MacCurdy):
Plates 1–8 ..... 500

Ancient seating furniture (Hough):
Plates 1–24 ..... 518

Aboriginal decorative art (Krieger):
Plates 1–37 ..... 556

The Holland Tunnel (Gray and Hagen):
Plates 1–30 ..... 608

Fewkes (Swanton and Roberts):
Plate 1 ..... 609

Merrill (Schuchert):
Plate 1 ..... 617

# ANNUAL REPORT OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION FOR THE YEAR ENDING JUNE 30, 1930

SUBJECTS

1. Annual report of the secretary, giving an account of the operations and condition of the Institution for the year ending June 30, 1930, with statistics of exchanges, etc.

2. Report of the executive committee of the Board of Regents, exhibiting the financial affairs of the Institution, including a statement of the Smithsonian fund, and receipts and expenditures for the year ending June 30, 1930.

3. Proceedings of the Board of Regents for the fiscal year ending June 30, 1930.

4. General appendix, comprising a selection of miscellaneous memoirs of interest to collaborators and correspondents of the Institution, teachers, and others engaged in the promotion of knowledge. These memoirs relate chiefly to the calendar year 1930.

# THE SMITHSONIAN INSTITUTION

June 30, 1930

*Presiding officer ex officio.*—HERBERT HOOVER, President of the United States.
*Chancellor.*—CHARLES EVANS HUGHES, Chief Justice of the United States.
*Members of the Institution:*

HERBERT HOOVER, President of the United States.
CHARLES CURTIS, Vice President of the United States.
CHARLES EVANS HUGHES, Chief Justice of the United States.
HENRY L. STIMSON, Secretary of State.
ANDREW W. MELLON, Secretary of the Treasury.
PATRICK J. HURLEY, Secretary of War.
WILLIAM D. MITCHELL, Attorney General.
WALTER F. BROWN, Postmaster General.
CHARLES FRANCIS ADAMS, Secretary of the Navy.
RAY LYMAN WILBUR, Secretary of the Interior.
ARTHUR M. HYDE, Secretary of Agriculture.
ROBERT P. LAMONT, Secretary of Commerce.
JAMES JOHN DAVIS, Secretary of Labor.

*Regents of the Institution:*

CHARLES EVANS HUGHES, Chief Justice of the United States, Chancellor.
CHARLES CURTIS, Vice President of the United States.
REED SMOOT, Member of the Senate.
JOSEPH T. ROBINSON, Member of the Senate.
CLAUDE A. SWANSON, Member of the Senate.
ALBERT JOHNSON, Member of the House of Representatives.
R. WALTON MOORE, Member of the House of Representatives.
ROBERT LUCE, Member of the House of Representatives.
ROBERT S. BROOKINGS, citizen of Missouri.
IRWIN B. LAUGHLIN, citizen of Pennsylvania.
FREDERIC A. DELANO, citizen of Washington, D. C.
DWIGHT W. MORROW, citizen of New Jersey.
JOHN C. MERRIAM, citizen of Washington, D. C.

*Executive committee.*—FREDERIC A. DELANO, R. WALTON MOORE, JOHN C. MERRIAM.
*Secretary.*—CHARLES G. ABBOT.
*Assistant Secretary.*—ALEXANDER WETMORE.
*Chief Clerk and administrative assistant to the Secretary.*—HARRY W. DORSEY.
*Treasurer and disbursing agent.*—NICHOLAS W. DORSEY.
*Editor.*—WEBSTER P. TRUE.
*Librarian.*—WILLIAM L. CORBIN.
*Appointment clerk.*—JAMES G. TRAYLOR.
*Property clerk.*—JAMES H. HILL.

## NATIONAL MUSEUM

*Assistant Secretary (in charge).*—ALEXANDER WETMORE.
*Administrative assistant to the Secretary.*—WILLIAM DE C. RAVENEL.
*Head curators.*—WALTER HOUGH, LEONHARD STEJNEGER, RAY S. BASSLER.

*Curators.*—PAUL BARTSCH, RAY S. BASSLER, THEODORE T. BELOTE, AUSTIN H. CLARK, FRANK W. CLARKE, FREDERICK V. COVILLE, W. F. FOSHAG, HERBERT FRIEDMANN, CHARLES W. GILMORE, WALTER HOUGH, LELAND O. HOWARD, ALEŠ HRDLIČKA, NEIL M. JUDD, HERBERT W. KRIEGER, FREDERICK L. LEWTON, GERRIT S. MILLER, JR., CARL W. MITMAN, CHARLES E. RESSER, WALDO L. SCHMITT, LEONHARD STEJNEGER.

*Associate curators.*—JOHN M. ALDRICH, CHESTER G. GILBERT, ELLSWORTH P. KILLIP, WILLIAM R. MAXON, CHARLES W. RICHMOND, DAVID WHITE.

*Chief of correspondence and documents.*—HERBERT S. BRYANT.

*Disbursing agent.*—NICHOLAS W. DORSEY.

*Superintendent of buildings and labor.*—JAMES S. GOLDSMITH.

*Editor.*—MARCUS BENJAMIN.

*Assistant Librarian.*—LEILA G. FORBES.

*Photographer.*—ARTHUR J. OLMSTED.

*Property clerk.*—WILLIAM A. KNOWLES.

*Engineer.*—CLAYTON R. DENMARK.

## NATIONAL GALLERY OF ART

*Director.*—WILLIAM H. HOLMES.

## FREER GALLERY OF ART

*Curator.*—JOHN ELLERTON LODGE.

*Associate curator.*—CARL WHITING BISHOP.

*Assistant curator.*—GRACE DUNHAM GUEST.

*Associate.*—KATHARINE NASH RHOADES.

*Superintendent.*—JOHN BUNDY.

## BUREAU OF AMERICAN ETHNOLOGY

*Chief.*—MATTHEW W. STIRLING.

*Ethnologists.*—JOHN P. HARRINGTON, JOHN N. B. HEWITT, TRUMAN MICHELSON, JOHN R. SWANTON.

*Archeologist.*—FRANK H. H. ROBERTS, JR.

*Editor.*—STANLEY SEARLES.

*Librarian.*—ELLA LEARY.

*Illustrator.*—DE LANCEY GILL.

## INTERNATIONAL EXCHANGES

*Secretary (in charge).*—CHARLES G. ABBOT.

*Chief clerk.*—COATES W. SHOEMAKER.

## NATIONAL ZOOLOGICAL PARK

*Director.*—WILLIAM M. MANN.

*Assistant director.*—ERNEST P. WALKER.

## ASTROPHYSICAL OBSERVATORY

*Director.*—CHARLES G. ABBOT.

*Assistant director.*—LOYAL B. ALDRICH.

*Research assistant.*—FREDERICK E. FOWLE, JR.

*Associate research assistant.*—WILLIAM H. HOOVER.

## DIVISION OF RADIATION AND ORGANISMS

*Research associate in charge.*—FREDERICK S. BRACKETT.

*Consulting plant physiologist.*—EARL S. JOHNSTON.

*Research assistant.*—LELAND B. CLARK.

## REGIONAL BUREAU FOR THE UNITED STATES, INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE

*Assistant in charge.*—LEONARD C. GUNNELL.

# REPORT

OF THE

# SECRETARY OF THE SMITHSONIAN INSTITUTION

C. G. ABBOT

## FOR THE YEAR ENDING JUNE 30, 1930

*To the Board of Regents of the Smithsonian Institution:*

GENTLEMEN: I have the honor to submit herewith my report showing the activities and condition of the Smithsonian Institution and the Government bureaus under its administrative charge during the fiscal year ended June 30, 1930. The first 24 pages contain a summary account of the affairs of the Institution. Appendixes 1 to 11 give more detailed reports of the operations of the United States National Museum, the National Gallery of Art, the Freer Gallery of Art, the Bureau of American Ethnology, the International Exchanges, the National Zoological Park, the Astrophysical Observatory, the Division of Radiation and Organisms, the United States Regional Bureau of the International Catalogue of Scientific Literature, the Smithsonian library, and of the publications issued under the direction of the Institution; and Appendix 12 contains a list of subscribers since November 15, 1929, to the James Smithson Memorial Edition of the Smithsonian Scientific Series.

## THE SMITHSONIAN INSTITUTION

### OUTSTANDING EVENTS OF THE YEAR

Several events of unusual importance to the Institution have occurred during the year just passed, and its scientific work has progressed in a satisfactory manner. To mention some of the high-lights of the year's advance, Congress authorized an appropriation for the construction of the much-needed wings on the Natural History Building of the National Museum at a cost not to exceed $6,500,000. The work of the Astrophysical Observatory has shown an apparently large and important influence of small short-period solar variations on the temperature in the United States. The new Division of Radia-

tion and Organisms has made rapid progress in the construction and equipment of laboratories for physical, chemical, and biological investigations, and has already obtained preliminary results in two highly interesting researches. Dr. R. H. Goddard, whose experiments in designing and building a rocket to explore the unknown upper layers of the atmosphere the Institution has aided for 12 years, brought the work to the point of practical demonstration. The late Simon Guggenheim, at Colonel Lindbergh's suggestion, has made a large grant to complete this development under most favorable auspices. Dr. C. U. Clark, under a grant from Ambassador Charles G. Dawes, has made important discoveries of unpublished early Spanish-American records in European archives. Four more volumes of the Smithsonian Scientific Series were practically ready to be issued at the close of the year, making eight volumes completed, and the last four are well advanced in preparation. Substantial sums have already been received by the institution as royalties on the sale of this series. The fifth and sixth awards of the Langley Gold Medal for Aerodromics were made to Charles Matthews Manly and Commander (now Admiral) Richard Evelyn Byrd. Under the auspices of the Institution and its branches many expeditions went into the field to obtain necessary data and collections. Reference to these will be found in the following reports. Many monographs and smaller papers embodying the results of original researches have been published and widely distributed throughout the world.

## THE ESTABLISHMENT

The Smithsonian Institution was created by act of Congress in 1846, according to the terms of the will of James Smithson, of England, who, in 1826, bequeathed his property to the United States of America "to found at Washington, under the name of the Smithsonian Institution, an establishment for the increase and diffusion of knowledge among men." In receiving the property and accepting the trust, Congress determined that the Federal Government was without authority to administer the trust directly, and therefore constituted an "establishment" whose statutory members are "the President, the Vice President, the Chief Justice, and the heads of the executive departments."

## THE BOARD OF REGENTS

The affairs of the Institution are administered by a Board of Regents whose membership consists of "the Vice President, the Chief Justice, three members of the Senate, and three Members of

the House of Representatives, together with six other persons other than Members of Congress, two of whom shall be resident in the city of Washington and the other four shall be inhabitants of some State, but no two of them the same State." One of the Regents is elected chancellor by the board; in the past the selection has fallen upon the Vice President or the Chief Justice; and a suitable person is chosen by the Regents as Secretary of the Institution, who is also secretary of the Board of Regents, and the executive officer directly in charge of the Institution's activities.

The only change occurring in the personnel of the board during the year was the resignation of Chief Justice Taft and his succession by Charles Evans Hughes, both as Chief Justice and as Chancellor of the Board of Regents.

The roll of the Regents at the close of the fiscal year was as follows: Charles Evans Hughes, Chief Justice of the United States, chancellor; Charles Curtis, Vice President of the United States; members from the Senate, Reed Smoot, Joseph T. Robinson, Claude A. Swanson; members from the House of Representatives, Albert Johnson, R. Walton Moore, Robert Luce; citizen members, Robert S. Brookings, Missouri; Irwin B. Laughlin, Pennsylvania; Frederic A. Delano, Washington, D. C.; Dwight W. Morrow, New Jersey; and John C. Merriam, Washington, D. C.

## FINANCES

The permanent investments of the Institution consist of the following:

| | |
|---|---|
| Total endowment for general or specific purposes (exclusive of Freer funds) | $1,670,582.40 |
| Itemized as follows: | |
| Deposited in the Treasury of the United States, as provided by law | 1,000,000.00 |
| Deposited in the consolidated fund: | |
| Miscellaneous securities, etc., either purchased or acquired by gift; cost or value at date acquired | 578,292.40 |
| Springer, Frank, fund for researches, etc. (bonds) | 30,000.00 |
| Walcott, Charles D. and Mary Vaux, fund for researches, etc. (stocks and bonds) | 12,477.50 |
| Younger, Helen Walcott, fund (real estate notes and stock, held in trust) | 49,812.50 |
| Total | 1,670,582.40 |

The above mentioned funds of the Institution are described as follows:

| Fund | United States Treasury | Consolidated fund | Separate funds | Total |
|---|---|---|---|---|
| Bacon, Virginia Purdy, fund | | $65,812.09 | | $65,812.09 |
| Baird, Lucy H., fund | | 2,076.68 | | 2,076.68 |
| Canfield Collection, fund | | 50,242.50 | | 50,242.50 |
| Casey, Thomas L., fund | | 6,416.97 | | 6,416.97 |
| Chamberlain fund | | 36,990.04 | | 36,990.04 |
| Hodgkins (specific), fund | $100,000.00 | | | 100,000.00 |
| Hughes, Bruce, fund | | 17,942.72 | | 17,942.72 |
| Myer, Catherine W., fund | | 21,700.97 | | 21,700.97 |
| Pell, Cornelia Livingston, fund | | 3,171.41 | | 3,171.41 |
| Poore, Lucy T. and Geo. W., fund | 26,670.00 | 31,478.61 | | 58,148.61 |
| Reid, Addison T., fund | 11,000.00 | 12,476.50 | | 23,476.50 |
| Roebling fund | | 158,524.06 | | 158,524.06 |
| Smithsonian unrestricted fund: | | | | |
| Avery fund | 14,000.00 | 48,914.74 | | 62,914.74 |
| Endowment fund | | 72,353.49 | | 72,353.49 |
| Habel fund | 500.00 | | | 500.00 |
| Hachenberg fund | | 5,285.01 | | 5,285.01 |
| Hamilton fund | 2,500.00 | 529.41 | | 3,029.41 |
| Henry fund | | 1,588.62 | | 1,588.62 |
| Hodgkins general fund | 116,000.00 | 39,394.24 | | 155,394.24 |
| Parent fund | 727,640.00 | 1,603.49 | | 729,243.49 |
| Rhees fund | 590.00 | 621.33 | | 1,211.33 |
| Sanford fund | 1,100.00 | 1,169.52 | | 2,269.52 |
| Springer, Frank, fund | | | $30,000.00 | 30,000.00 |
| Walcott, Charles D. and Mary Vaux, fund | | | 12,477.50 | 12,477.50 |
| Younger, Helen Walcott, fund | | | 49,812.50 | 49,812.50 |
| Total | 1,000,000.00 | 578,292.40 | 92,290.00 | 1,670,582.40 |

The Institution gratefully acknowledges gifts from the following donors:

Dr. W. L. Abbott, for archeological expedition to Hispaniola and other places.

Mrs. Laura Welsh Casey, for further contributions to the Thomas Lincoln Casey fund for researches in Coleoptera.

Mr. Childs Frick, for researches in vertebrate paleontology.

Harvard University, for contribution toward purchase of meteorite.

Missouri Historical Society, for further study of the language of the Osage Indians.

National Academy of Sciences (through Dr. Hrdlička), for archeological explorations in Alaska.

Research Corporation, for further contributions for research in radiation.

Mr. John A. Roebling, for further contributions for researches in radiation and studies in world weather records.

Dr. William Schaus, for purchase of specimens of Lepidoptera.

Mrs. Mary R. Swales, for expenses of publications in connection with Swales fund.

Mr. Hans Wilkens, of Reading, Pa., for general endowment fund of the Institution.

*Freer Gallery of Art.*—The invested funds of the Freer bequest are classified as follows:

| | |
|---|---|
| Court and grounds fund | $592,046.60 |
| Court and grounds maintenance fund | 149,608.46 |
| Curator fund | 602,395.38 |
| Residuary legacy | 3,956,879.06 |
| Total | 5,300,929.50 |

The practice of depositing on time in local trust companies and banks such revenues as may be spared temporarily has been continued during the past year, and interest on these deposits has amounted to $8,103.31.

*Cash balances, receipts and disbursements during the fiscal year*[1]

| | | |
|---|---|---|
| Cash balance on hand June 30, 1929 | | $216,994.28 |
| Receipts: | | |
| Cash from invested endowments and from miscellaneous sources for general use of the Institution | $74,850.62 | |
| Cash for increase of endowments for specific use | 1,029.57 | |
| Cash gifts for increase of endowments for general use | 189.10 | |
| Cash gifts, etc., for specific use (not to be invested) | 105,710.88 | |
| Cash received as royalties from sales of Smithsonian Scientific Series[2] | 21,833.92 | |
| Cash gain from sale, etc., of securities (to be invested) | 2,170.13 | |
| Cash income from endowments for specific use other than Freer endowment, and from miscellaneous sources | 72,078.30 | |
| Cash capital from sale, call of securities, etc. (to be reinvested) | 175,357.85 | |
| Total receipts other than Freer endowment | | 453,220.37 |
| Cash receipts from Freer endowment—income from investments | $303,780.87 | |
| Net gain from sale, etc., of securities (to be invested) | 38,480.34 | |
| Cash capital from sale, call of securities, etc. (to be reinvested) | 1,432,644.95 | |
| | | 1,774,906.16 |
| Total | | 2,445,120.81 |
| Disbursements: | | |
| From funds for general work of the Institution— | | |
| Buildings, care, repairs and alteration | 1,937.05 | |
| Furniture and fixtures | 529.17 | |
| General administration[3] | 24,154.26 | |
| Library | 3,170.37 | |
| Publications (comprising preparation, printing and distribution) | 13,224.93 | |

[1] This statement does not include Government appropriations under the administrative charge of the Institution.

[2] Under resolution of the Board of Regents three-fourths of this income is credited to the permanent endowment fund of the Institution and one-fourth is made expendable for general purposes.

[3] This includes salaries of the secretary and certain others.

| | | |
|---|---|---|
| Disbursements—Continued. | | |
| From funds for general work of the Institution—Continued. | | |
| Researches and explorations | $19,294.39 | |
| International exchanges | 4,830.35 | |
| | | $67,140.52 |
| From funds for specific use other than Freer endowment: | | |
| Investments made from gifts, from gain, from sales, etc., of securities and from saving on income | 20,659.95 | |
| Other expenditures, consisting largely of research work, travel, increase and care of special collections, etc., from income of endowment funds and cash gifts for specific use | 147,063.31 | |
| Cash capital from sale, call of securities, etc., reinvested | 174,900.30 | |
| | | 342,623.56 |
| From Freer endowment: | | |
| Operating expenses of gallery, salaries, purchases of art objects, field expenses, etc | 337,207.13 | |
| Investments made from gain from sale, etc., of securities and from income | 50,045.48 | |
| Cash capital from sale, call of securities, etc., reinvested | 1,433,233.95 | |
| | | 1,820,486.56 |
| Balance June 30, 1930 | | 214,870.17 |
| Total | | 2,445,120.81 |

*Recapitulation of receipts, exclusive of Freer funds, during the year ending June 30, 1930*

| | | |
|---|---|---|
| General uses: | | |
| For addition to endowment | $16,564.55 | |
| Reserved as income | 80,309.09 | |
| | | $96,873.64 |
| Specific uses: | | |
| Gifts accretions to endowment | 1,000.00 | |
| Gifts for specific use not to be invested | 105,710.88 | |
| Cash income from endowments for addition to endowment | 6,961.38 | |
| Cash income from endowments and from other sources for conducting researches, explorations, etc | 67,316.62 | |
| Cash capital from sale, call of securities, etc. (to be reinvested) | 175,357.85 | |
| | | 356,346.73 |
| Total receipts exclusive of Freer funds | | 453,220.37 |

*Statement of endowment funds*

| | General purposes | Specific purposes other than Freer endowment | Freer endowment |
|---|---|---|---|
| Endowment, June 30, 1929 | $1,022,385.75 | $626,003.70 | $5,236,054.02 |
| Increase from income, gifts, etc | 1,418.00 | 8,825.19 | 11,602.60 |
| Increase from gain from sales, etc | 9,531.19 | 885.57 | 38,442.88 |
| Increase from stock dividends | 454.91 | 1,078.09 | 14,830.00 |
| Endowment June 30, 1930 | 1,033,789.85 | 636,792.55 | 5,300,929.50 |

The following appropriations were made by Congress for the Government bureaus under the administrative charge of the Smithsonian Institution for the fiscal year 1930:

| | | |
|---|---|---|
| Salaries and expenses | | $36,004.00 |
| Gellatly Art Collection | | 21,000.00 |
| International Exchanges | | 51,297.00 |
| American Ethnology | | 68,800.00 |
| International Catalogue of Scientific Literature | | 7,885.00 |
| Astrophysical Observatory | | 36,720.00 |
| National Museum: | | |
| Furniture and fixtures | $33,240.00 | |
| Heating and lighting | 90,160.00 | |
| Preservation of collections | 570,084.00 | |
| Building repairs | 21,080.00 | |
| Books | 2,000.00 | |
| Postage | 450.00 | |
| | | 717,014.00 |
| National Gallery of Art | | 34,853.00 |
| National Zoological Park | | 203,000.00 |
| National Zoological Park, building for reptiles | | 220,000.00 |
| National Zoological Park, gates for south boundary | | 2,000.00 |
| Printing and binding | | 95,000.00 |
| Total | | 1,493,573.00 |

## MATTERS OF GENERAL INTEREST

### AWARD OF LANGLEY MEDAL TO CHARLES MATTHEWS MANLY AND TO COMMANDER RICHARD EVELYN BYRD, UNITED STATES NAVY

The fifth and sixth awards of the Langley Gold Medal for Aerodromics to Charles Matthews Manly (posthumously) and to Commander (now Admiral) Richard Evelyn Byrd, United States Navy, were made at the Annual Meeting of the Board of Regents of the Institution on December 12, 1929. The medal had been hitherto awarded four times, to Wilbur and Orville Wright, to Glenn H. Curtiss, to Gustave Eiffel, and to Charles A. Lindbergh. The award

to Mr. Manly was made in recognition of his pioneer contributions to the development of the airplane engine, and that to Commander Byrd for his pioneer flights over the North and South Poles, his nonstop flight over the Atlantic Ocean, and the scientific discoveries associated with these flights.

The posthumous award to Mr. Manly will be presented through the person of his son. Commander Byrd was notified of the award to him by radiogram to Little America, Antarctica. The actual presentation of the two gold medals had not been made at the close of the year.

### ADDITIONS TO THE NATURAL HISTORY BUILDING OF THE NATIONAL MUSEUM

An event of capital importance to the future of the Smithsonian and the National Museum occurred on June 19, 1930, when Congress passed the following bill:

*Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled*, That the Smithsonian Institution is hereby authorized to extend the Natural History Building of the United States National Museum by additions on the east and west ends thereof, in accordance with plans to be approved by the Commission of Fine Arts, and to engage, if necessary, architectural and inspection services, without regard to the restrictions of existing law governing such services. There is hereby authorized to be appropriated a sum not exceeding $6,500,000 for this purpose.

The present Natural History Building has for years been overcrowded, both as to exhibition halls and to laboratories and storage rooms. The additions authorized by Congress, which will approximately double the present floor space, will not only permit of a more satisfactory arrangement of exhibits for the benefit of the more than one million visitors every year, but also will provide additional facilities for the growing research work of the Museum staff.

The bill quoted above is only an authorization and does not carry an actual appropriation. Plans have not yet been prepared, but in general the additions will conform in style and general arrangement with the present structure.

### RESEARCHES IN EUROPEAN ARCHIVES

Early in 1929 Ambassador Charles G. Dawes provided the Institution with a fund for the purpose of conducting researches among European archives in search of documents relating to the early history and ethnology of middle America. In April, 1929, Dr. C. U. Clark was appointed by the Smithsonian to conduct this mission, and early in October Doctor Clark began his work in Europe. Since that

time he has studied diligently at several of the principal archives containing early American material and has discovered a considerable number of valuable early manuscripts hitherto unpublished. In addition to the titles listed below Doctor Clark has excerpted many hundreds of pages of interesting ethnological material relating to the Americas from manuscripts which were not of special interest in their complete form, such as reports, letters, etc. The manuscripts copied and prepared for publication are as follows:

*Vatican Library.*—Reginus Lat. 1608. Contains four leaves containing a Nahuatl vocabulary and Nahuatl sentences for priests learning the language. Twelve typewritten pages.

*Vatican Library.*—Codex Barberini. Latinus 241. Written in Latin 1552 by Indian trained by Franciscans. Illustrated by 185 aquarelles in color representing plants and flowers. Sixty-three folios 6 by 8¼.

*Saville, Archivos Nacional.*—Guatemala No. 45. Maya-Aztec manuscript, being the village record book of San Juan Amatitlan, Guatemala 1559–1562. Written partially in the Pokoman dialect of Maya. Over 300 entries in Maya, in addition to a quantity of Aztec material.

*Archivos Nacional.*—Saville, Guatemala 128. Account of the official assessment of 1548–1550 for the Indian Pueblos of Guatemala, Nicaragua, Yucatan, and Comayagua. This gives an accurate census of Yucatan. Four hundred folios; 54 typewritten pages. Indian census of 1549. Made under direction of Diaz de Castillo.

*Biblioteca de Catalunya, Barcelona.*—Vocabulary of Tahitian language, 1774. Eight and one-half pages of two columns; 80 words to a page. Three and one-half pages of information derived from the Tahitians. Three pages of a list of 100 questions to be put to natives.

*Vatican Library.*—Barberini Lat. 3584. "Compendos y Descripcion de la Indias Ocodentales." Fray Antonio Vazquez de Espinosa, 1629. A voluminous compendium of information concerning the natives of South America, Central America, and the West Indies. Regarded by experts as of extraordinary value.

*Madrid. Biblioteca Nacional 19267.*—"Aulagoya's letter from Cali," 1540. Forty-three typewritten pages. An official description of the native tribes of Colombia.

### ROCKET EXPERIMENTS OF DR. R. H. GODDARD

For the past 12 years the Institution has supported by annual grants the researches of Dr. R. H. Goddard, of Clark University, on the development of a rocket to explore the upper atmosphere. In 1916 Doctor Goddard presented to the Institution such a convincing mathematical demonstration of the theory that a self-propelling rocket could be sent to the limit of the earth's atmosphere, and even beyond, that Doctor Walcott, then Secretary of the Smithsonian, after consultation with a committee of experts, agreed to support the investigation. The work progressed so favorably that the Institution has continued its support until the present time.

The highest level of the air which can now be studied is about 20 miles up, reached by sounding balloons, but these balloons often drift as much as 150 miles from their starting point, and their recovery is slow and uncertain. A rocket, on the other hand, would go straight up to any desired height and provided with a parachute would return in a short time at or very near its starting point. With suitable automatic apparatus, such a rocket could bring back samples of the upper air for chemical analysis, measure the temperature and pressure of the higher atmosphere, expose spectographs above the ozone layer where the ultra-violet spectrum of the sun could be observed, and record the condition of the atmosphere from 5,000 feet upward in the interests of aviation. In short, a whole new field of investigation would be opened up—the unknown upper layers of the earth's atmosphere.

This investigation was pioneering in character; little was available as a guide. After much experimenting with a rocket equipped with a device for feeding small charges of high explosive, Doctor Goddard turned finally to the scheme of a steady combustion of hydrocarbon in liquid oxygen. After further modifying the design of the rocket itself to adapt it to the use of this new means of propulsion, Doctor Goddard was ready at the close of the fiscal year for an actual field trial of the device.

It may be said that on July 17, 1929, a trial of the liquid-propelled rocket was made at Worcester, Mass., the device functioning satisfactorily as regards the flow of liquid, the ascent of the rocket, and its rapid motion in air. The trial rocket was guided only by vanes on its rear end, and these proved inefficient, the rocket describing a high arch and returning to the ground instead of making a vertical flight. Doctor Goddard has already designed automatic stabilizers, however, and these together with the necessary automatic recording devices are seemingly all that is needed to insure a successful, practical flight of the rocket to the higher layers of the atmosphere and its return with the first records of an unknown region.

The apparently assured success of Doctor Goddard's experiments has drawn support from a source better equipped financially to provide it than the Smithsonian. The late Simon Guggenheim at Colonel Lindbergh's suggestion made a large grant of funds and set up an advisory committee of which the secretary, Doctor Abbot, is a member. Doctor Goddard's experiments are now going on under these auspices in New Mexico. It is a pleasure to record here that the Smithsonian has again been able to support during its more or less uncertain pioneering stages an investigation of great promise for the increase of knowledge.

### LOW TEMPERATURE RESEARCHES

The Smithsonian has made two small grants during the year to Prof. Dr. W. H. Keesom, director of the Cyrogenic Laboratory at Leiden, in aid of his important researches on the properties of matter at very low temperatures. Two investigations were in progress by Doctor Keesom, with the aid of his collaborators, namely, the measurement of the specific heat of gases at very low temperatures, and the measurement of the thermomolecular pressure differences at very low temperatures.

In connection with the first, it seemed desirable to obtain measurements on the specific heat of helium gas at the temperatures obtainable with liquid helium. Such a measurement had already been made by Meissner in Berlin, who found the specific heat of helium gas at a temperature of 5.5° K. (approximately −450° F.) and a pressure of 0.75 atmosphere to be about 65 per cent of the normal value, and ascribed this result to quantum effects. There is reason to doubt, however, whether quantum effects can be demonstrated in such a way because of the influence of intermolecular forces on specific heat. To investigate this matter, Doctor Keesom and his assistants elaborated a method of measuring the velocity of propagation of sound at these very low temperatures and at pressures smaller than 1 atmosphere. From this velocity, the specific heat may be derived.

Measurements of this velocity have already been made with great accuracy at the temperatures of liquid oxygen and of liquid hydrogen, and preliminary measurements have been made of the velocity of sound in helium gas at the temperature of liquid helium, but further developments in the method must be made for this last investigation.

Doctor Keesom's second research relates to the investigation of the thermomolecular pressure differences between the bulb of the helium thermometer and the manometer used in the measurement of the lowest temperatures obtainable. In his latest measurements the temperature recorded was 0.89° K. (approximately, =458° F.). Exact measurements of these pressure differences have now been made at the temperatures of boiling oxygen and of boiling hydrogen; measurements at the temperatures obtainable with liquid helium will follow.

### DIVISION OF RADIATION AND ORGANISMS

The report of the director on the first year's work of this new and important branch of the Smithsonian's investigations in physical science shows remarkably rapid progress. The construction of laboratories and their equipment has been particularly difficult because

of the borderline character of the researches; it was necessary to provide for physical, chemical, and biological fields of investigation. In spite of the constant construction and equipment problems, actual research work was started, and two experiments, the one on phototropism, the other on infra-red absorption of pure chemicals, were carried to interesting preliminary results.

Offices for the division were provided by remodelling the hitherto unused flag tower of the Smithsonian Building, and space in the basement previously used for storage was reconstructed into a modern physical, chemical, and biological laboratory. A small group of highly trained specialists has been assembled to carry on the investigations, and these men work in close cooperation with the Smithsonian Astrophysical Observatory, the Fixed Nitrogen Laboratory of the Agricultural Department, the University of Maryland, and the Research Corporation of New York.

The chief aim of the division is to build up a strong spectrophotometric laboratory, whose staff of physicists and technicians will work in cooperation with men of biological training. The researches to be undertaken fall into two classes: (1) Direct investigation upon living organisms, and (2) fundamental molecular structure and photochemical investigations related to the biological problems. In connection with the first, an experiment was made to determine the amount of bending of plants towards light of various wave lengths. Briefly, the experiment showed that red or infra-red light produced no effect; that yellow light produced a small but measurable bending; that green light was 1,000 times more effective than yellow; and that blue light was 30 times more effective than green, or 30,000 times more effective than yellow. These results are so interesting that preparations are under way for a more elaborate experiment.

Under the second heading above, no work could be undertaken at the Smithsonian because of lack of funds and shop equipment. Some progress was made, however, in the preparation of equipment, and through the cooperation of the Fixed Nitrogen Laboratory, Mr. Liddell of its staff continued an investigation begun there by Doctor Brackett before his appointment by the Smithsonian. This project, which was completed as far as the equipment permitted, involved the study of the near infra-red absorption spectra of the halogen deviations of benzene.

### EXPLORATIONS AND FIELD WORK

Expeditions in the field are essential to the Smithsonian's work in anthropology, biology, geology, and astrophysics. Twenty-eight major expeditions went out during the year to widely scattered regions, bringing back necessary information and valuable speci-

mens. The Institution bore the entire expense of a few of these expeditions. For the cost of the others, in part at least, it is indebted to friends of the Smithsonian or to other institutions equally interested in the proposed work.

The regions visited by the year's field expeditions included China, Alaska, Canada, the West Indies, South America, Africa, Europe, the Philippines, and Siam, as well as 13 localities in the United States. I may mention especially Assistant Secretary Dr. A. Wetmore's bird collecting expedition in Spain, Dr. Paul Bartsch's explorations for mollusks in the West Indies under the Walter Rathbone Bacon Travelling Scholarship; anthropological studies in Alaska by Dr. Aleš Hrdlička and Mr. Henry B. Collins, jr.; an extended botanical exploring trip in Amazonian Peru and Brazil, by Mr. Ellsworth P. Killip; and three separate expeditions to the island of Santo Domingo, namely, Mr. E. C. Leonard's botanical exploration of northwestern Haiti, Mr. Herbert W. Krieger's archeological work in the Dominican Republic, and Mr. Arthur J. Poole's explorations in Haitian caves.

Brief accounts of all of these expeditions, fully illustrated, appeared in "Explorations and Field-Work of the Smithsonian Institution in 1929," Smithsonian Publication No. 3060, and notices of some of them will be found in the reports of certain of the bureaus under the Institution's direction, appended hereto.

### COOPERATIVE ETHNOLOGICAL AND ARCHEOLOGICAL INVESTIGATIONS

In 1928 Congress authorized the appropriation of $20,000 for cooperative ethnological and archeological investigations in the several States. The Secretary of the Smithsonian Institution was designated to approve the investigations proposed, and if found desirable, to allot from the money appropriated a sum equal to that raised for the purpose by any State educational institution, or scientific organization in the United States. He was named also to direct the work and to divide the results thereof. Fifteen allotments for approved investigations have been made during the year, as follows:

*Allotments from the fund for cooperative ethnological and archeological investigations during the fiscal year ended June 30, 1930*

*1929*

Nov. 6. University of Nebraska, for an archeological survey of the Missouri, Platte, and Republican River Valleys in Nebraska, $1,000.

*1930*

Jan. 17. University of Chicago, for continuation of an archeological survey of Illinois, $1,000.

Mar. 17. Logan Museum, for archeological researches in Mandan villages, $1,000.

Mar. 17. University of Kentucky, for archeological researches in eastern and and western Kentucky, $500.

Mar. 21. University of California, for work among the Paviotso and Modoc in northeastern California, $250.
Mar. 21. University of California, for further work on Yokuts shamanism, $150.
Mar. 21. University of California, for a study of Yuki groups, $150.
Mar. 21. University of California, to continue and if possible complete work on northwestern California basketry, $150.
Mar. 21. University of California, for work on the Tolowa, a little known group of Athabascans in the extreme northwestern corner of California, $125.
Mar. 21. University of California, to continue work on the Northern Wintun, $100.
Mar. 21. San Diego Museum, for an archeological investigation of Los Angeles and Orange counties, $800.
Mar. 25. University of Illinois, for archeological investigation in the vicinity of Utica, Ill., $1,000.
April 4. University of Denver and Museum of Natural History of Denver, for an archeological survey of eastern Colorado, $1,500.
May 27. Phillips Academy, for an archeological survey of Merrimack Valley, $1,000.
June 13. Indiana Historical Bureau, to continue archeological survey of Indiana, $1,000.

The above list, with that given in my last annual report, will serve to indicate the widespread interest aroused through this cooperative project for the study and preservation of the Indian material and data in the various States.

## PUBLICATIONS

The publications of the Institution are issued in 11 distinct series, which total approximately 10,000 pages a year. The Institution proper publishes three of the series, namely, Smithsonian Annual Reports, Smithsonian Contributions to Knowledge, and Smithsonian Miscellaneous Collections; the other series are issued by the bureaus under Smithsonian direction. The Contributions to Knowledge, in quarto, which for many years was the best known of all of the series, has in recent years been suspended because the higher costs of printing made it impracticable to issue monographs in the more expensive quarto form. The Institution expects however to resume the Contributions when more resources become available.

A total of 95 volumes and pamphlets appeared during the year, and 168,163 copies of Smithsonian publications were distributed, including 19,575 volumes and separates of the Smithsonian Miscellaneous Collections, 29,886 volumes and separates of the Smithsonian Annual Reports, 4,598 Smithsonian special publications, 87,323 publications of the National Museum and 24,868 publications of the Bureau of American Ethnology. Titles and authors and other information regarding the year's publications are given in the report of the editor, appendix 11.

The Annual Report of the Board of Regents to Congress contained the usual General Appendix made up of articles in semipopular style to present the progress in nearly all branches of science during the year. These reports continue in wide demand, and many letters are received expressing appreciation of the Institution's efforts to give the nontechnical reader an authentic survey of the yearly advance along the scientific front.

### SMITHSONIAN SCIENTIFIC SERIES

As stated in my last report, the Institution decided in 1928 to issue a popular, profusely illustrated series of 12 volumes relating to the several branches of science coming within the scope of its activities, with the expectation that through the sale of this series, increased resources might become available for the furtherance of its scientific work. The sale of the books, known as the Smithsonian Scientific Series, is entirely in the hands of the New York publishers, the Smithsonian's part being only that of author.

Volumes one to four appeared in 1929, as follows:

1. The Smithsonian Institution, by Webster Prentiss True.
2. The Sun and the Welfare of Man, by Charles Greeley Abbot.
3. Minerals from Earth and Sky. Part I, The Story of Meteorites, by George P. Merrill; Part II, Gems and Gem Minerals, by William F. Foshag.
4. The North American Indians. An account of the American Indians north of Mexico, compiled from the original sources, by Rose A. Palmer.

Volumes five to eight were still in press at the close of the fiscal year, but were expected to be received from the printer very soon thereafter. They are as follows:

5. Insects: Their Ways and Means of Living, by R. E. Snodgrass.
6. Wild Animals in and out of the Zoo, by William M. Mann.
7. Man from the Farthest Past, by C. W. Bishop, C. G. Abbot, and A. Hrdlička.
8. Cold-Blooded Vertebrates, by C. W. Gilmore, D. M. Cochran, and S. F. Hildebrand.

The remaining four volumes are in press or in an advanced state of preparation, and will be issued during the coming year.

### LIBRARY

The Smithsonian library is composed of 10 divisional and 36 sectional libraries. The divisional libraries include the Smithsonian deposit in the Library of Congress, which is the Institution's main library, the office library, the Langley Aeronautical Library, and the seven libraries of the bureaus under administrative direction of the Institution, the largest of which is the National Museum library. This last includes the 36 sectional libraries, which are the working units kept in the various divisions of the Museum. The whole library numbers over 800,000 volumes, pamphlets, and charts. The year's accessions totaled 14,277 items, of which 7,979 were volumes and 6,298 were pamphlets and charts.

An important change during the year was the removal of the Langley Aeronautical Library from the Smithsonian Building to the Library of Congress, where although still remaining a unit of the Smithsonian library, it will be more centrally available to the student. Many gifts were received during the year, among which may be mentioned a collection of 1,400 volumes on various subjects from Mr. James Townsend Russell, jr.; 150 volumes and 1,000 periodicals chiefly on aeronautics from the National Aeronautic Association; and 58 volumes on Japanese history and literature from the Historiographical Institute, Tokyo.

Further progress was made on the union catalogue, but this large task will require many years for completion unless additional assistants are provided. The congested condition of the Museum library was relieved for the time being by the installation of 400 feet of new shelving.

The librarian notes that although two additional assistants are provided for in the coming year, six more are needed to enable the library to render the desired service to the work of the Institution.

## GOVERNMENTALLY SUPPORTED BRANCHES

### NATIONAL MUSEUM

The event of the year for the Museum was the passage of the Smoot-Elliott bill authorizing an appropriation for the extension of the Natural History Building by the construction of wings at the east and west ends at a cost of $6,500,000. These additions, which will follow the style and general arrangement of the present building, will relieve the greatly overcrowded condition of the offices and exhibition halls, and also will permit of normal expansion of the national collections which are the foundation for researches in pure science and consequently for their application to the welfare of mankind.

The appropriations for the maintenance of the Museum for the year totaled $762,514, an increase of $14,490, of which $9,500 provided for salaries of five additional positions, namely an assistant curator of mollusks, an additional clerk in the administrative office, and three sergeants of the watch. These additions to the personnel were of great benefit to the Museum's work, but several offices are still undermanned, both as to scientific and clerical workers.

Additions to the collections during the year totaled 410,815 specimens, the majority coming to the department of biology. Material sent in for expert examination and report numbered 1,306 lots, and gifts of duplicate material to schools totaled 11,474 specimens. Exchanges to the number of 12,649 specimens were sent out, and 33,208 were loaned to scientific workers outside of Washington.

Large collections of material representing the Indian and Eskimo tribes of Alaska came to the department of anthropology through the field work there by Dr. Aleš Hrdlička and Mr. Henry B. Collins, jr. There may also be mentioned an ethnological collection from Nigeria and the gold and ivory coasts of Africa, from Mr. C. C. Roberts; prayer stones and other objects of a religious nature from Tibet, presented by Mr. Charles S. Isham; and ethnological material from the Dominican Republic collected by Mr. H. W. Krieger.

Among the great amount of material received by the department of biology there stand out extensive collections given by the National Geographic Society, including birds and plants brought from western China by Dr. Joseph F. Rock and insects and plants from northern Brazil collected by Mr. E. G. Holt; further general natural history collections made in China by the Rev. D. C. Graham; biological material from Siam from Dr. Hugh M. Smith; and a very complete series of birds' eggs from Mr. A. C. Bent.

The most important single object received by the department of geology was the great flawless crystal ball 12⅞ inches in diameter presented by Mrs. Worcester Reed Warner as a memorial to her husband. Through the income of the Roebling fund and of the Frances Lea Chamberlain fund, a considerable number of fine mineral specimens and gem stones were added to the collections. Through the field work of Resser, Gilmore, Gidley, and others of the Museum staff, large and valuable collections of fossils have been added.

Many interesting accessions came to the arts and industries department, prominent among them being the gift by Mr. Rudolph Eickemeyer of a large series of examples of his own work in pictorial photography, together with a library of works on photography. Mr. Eickemeyer has provided in his will a fund for the care of the collection. The division of history received among other historical material five pieces of china used in the White House by President James Madison, presented by Miss Mary M. McGuire, and a gown worn by Mrs. Calvin Coolidge presented for the costume collection by Mrs. Coolidge.

A large number of field expeditions went out under the direction of members of the Museum staff, financed chiefly by the private income of the Smithsonian Institution or through the aid of interested friends and patrons. These expeditions are described briefly in the report of the National Museum, Appendix 1.

The lecture rooms and auditorium of the Museum were used by Government and other agencies for hearings, meetings, and lectures to the number of 135. Visitors to the Museum totalled 1,894,989 for the year. Sixteen volumes and 35 pamphlets were published, and 87,323 copies of Museum publications were distributed.

## NATIONAL GALLERY OF ART

The leading event of the year was the exhibition in the gallery of the 78 American paintings purchased during the last 10 years from the Ranger fund, which are subject to consideration as additions to the gallery's permanent collections as provided in the Ranger bequest. The paintings were lent for the exhibition by the institutions to which they were assigned by the National Academy of Design. The exhibition was opened on December 10, 1929, with a reception by the Secretary and Regents of the Institution, the Director of the National Gallery, and the members of the National Gallery of Art Commission; the National Academy of Design was represented by six of its officials.

Besides the exhibition of Ranger paintings, four special exhibits were held during the year, namely, sculpture of Edgardo Simone, portraits by Edwin B. Child, paintings, sculptures, etc., by contemporary Hungarian artists, and paintings by American Negro artists.

## FREER GALLERY OF ART[4]

Additions to the collections by purchase during the year include examples of early Egyptian bookbinding; Chinese bronzes; Chinese jade objects; Persian and Egyptian manuscripts; Persian, Indian, Chinese, and Egyptian paintings; Chinese porcelain bowls; Chinese pottery; South Indian bronze sculpture; Chinese silver objects; and Chinese silver-gilt objects.

Curatorial work included the documentary study of inscriptions on new purchases as well as those on objects already in the collection. Expert opinion was given to other institutions and individuals regarding 834 objects and 185 photographs of objects sent in for examination. With the expert aid of Dr. A. K. Coomaraswamy, a large group of paintings in the Near Eastern section, purchased in 1907 from Col. H. B. Hanna, has undergone complete revision and reclassification.

The year's total attendance was 120,651; of these 1,349 visited the offices for general information or for study purposes. Sixteen groups were given docent service in the exhibition galleries, and 10 classes were given instruction in the study room. Two lectures were given in the auditorium: "The Caves of the Thousand Buddhas," by Sir Aurel Stein; and "Indian Sculpture: Intention and Development," by Dr. A. K. Coomaraswamy.

The field expedition was able, in spite of disturbed conditions, to make interesting investigations at the site of the Liang dynasty (A. D. 502–556) tombs, near Nanking, China.

[4] The Government's expense in connection with the Freer Gallery of Art consists mainly in the care of the building and certain other custodial matters. Other expenses are paid from the Freer endowment funds.

## BUREAU OF AMERICAN ETHNOLOGY

The work of the bureau covered the usual wide range of ethnological and archeological investigations on many Indian tribes and sites of the United States. The chief, Mr. M. W. Stirling, made an archeological reconnaissance of the Ten Thousand Islands, Fla., and excavated mounds at Lacooche and at Safety Harbor, Fla. He delivered lectures before numerous scientific and educational bodies. Dr. John R. Swanton continued his field work on the Choctaw of Mississippi and the Creeks of Oklahoma, and began the work of translating the words of his Timucua dictionary. Dr. Truman Michelson studied the Algonquian tribes of Oklahoma, and Mr. John P. Harrington obtained much of the language and ethnology of the San Juan Tribe of California through an aged informant.

Dr. F. H. H. Roberts, jr., conducted extensive archeological excavations at the Long H Ranch, in eastern Arizona, revealing 18 pit houses, 3 jacal, pole, and mud structures, and a pueblo ruin containing 49 rooms and 4 kivas. Mr. J. N. B. Hewitt continued his studies of the Iroquois Indians of Canada and New York State, and Dr. Francis LaFlesche nearly completed his Osage dictionary before his retirement on December 26, 1929. Miss Frances Densmore studied the music of 10 tribes—the Acoma, Menominee, Winnebago, Yuma, Cocopa, Mohave, Yagui, Makah, Clayoquot, and Quilente.

Five bulletins and a list of publications of the bureau were issued during the year, and a total of 24,868 copies of bureau publications were distributed.

## INTERNATIONAL EXCHANGE SERVICE

The Exchange Service handled during the year a total of 694,665 packages of governmental, scientific, and literary publications, which represented a total weight of 708,094 pounds. This constitutes an increase of 12 per cent in number of packages, and 14 per cent in weight over the previous year.

The material handled by the Exchange Service includes publications received from this country for transmission to foreign countries, and also those sent from abroad for distribution to addresses in this country. They are classified as parliamentary documents, departmental documents, and miscellaneous scientific and literary publications. The parliamentary and departmental documents include all matter published by Congress and by the Government departments, bureaus, and commissions. These constitute the bulk of the publications handled by the Exchange Service, 74 per cent of the work of the office being conducted in behalf of the United States governmental establishments. The miscellaneous scientific and literary publications are received for distribution chiefly from learned societies, educational institutions, scientific organizations, and museums.

## NATIONAL ZOOLOGICAL PARK

Animals added to the collection during the year numbered 759, while 974 were removed through death, exchange, and return of animals, the collection standing at 1,996 at the close of the year. Owing to lack of further housing facilities, it has been necessary to choose very carefully in making additions to the collection, with the result that the park now contains a great many rarities, including a number of species not shown in any other American zoo.

The total attendance at the park was estimated at 2,525,141, about the same as in the preceding year. This total included 28,814 students from 465 different schools. The value of the park as an educational institution, quite apart from its recreational value, is coming to be more and more recognized. Here may be seen visitors of all ages and all degrees of learning, from the young child to the veteran research worker and the advanced medical man, each of whom can learn something of value concerning animals and animal life.

Construction of the new reptile house authorized by Congress was started in March, 1930. The best modern ideas as to the exhibition of reptiles will be incorporated in the building, which will permit the National Zoo to show for the first time an adequate representation of these interesting creatures. The next most urgently needed building is one for small mammals, with which also would be exhibited the great apes; these latter are at present shown in inadequate cages where comparatively few people can see them at a time.

## ASTROPHYSICAL OBSERVATORY

The central station at Washington and the three observing stations on Mount Montezuma, Chile; Table Mountain, Calif.; and Mount Brukkaros, South West Africa, have continued the exact measurement of the intensity of the radiation of the sun as it is at mean solar distance outside the earth's atmosphere. The values from Mount Montezuma have continued to be satisfactory and are cabled to Washington each day; the values from Table Mountain are found to be influenced by the haziness or humidity of the atmosphere, and a new method of reduction to allow for these effects was being developed at the close of the year, preliminary trials of which give promising results. Reduction of Mount Brukkaros observations is being postponed until this method is further tested for Table Mountain.

It has recently been discovered that a variation of large percentage exists in the quantity of ozone at high levels above Table Mountain. In order to make ozone corrections to solar constant values obtained there from the year 1925 on, it became necessary to devise a method

of computing the correction from the daily solar constant observations themselves, and this was successfully accomplished during the year.

The most important feature of the year's work was the discovery of an apparently considerable influence of short-period solar variation on the temperature of the United States. The variations as recorded through six consecutive years at Mount Montezuma were compared with temperature changes in Washington, Williston, and Yuma, selecting for the purpose sequences of ascending and descending solar radiation values occupying about four days per sequence. Corresponding to the average change of 0.8 per cent in the sun, there appear to be temperature changes of the order of 5° F. in Washington. The sign of the correlation changes in a very interesting way during the year. Although this relation is complicated, it offers promise for weather forecasting nearly a week in advance. These are tentative results. It is proposed to study barometric pressures as well as temperatures, and to extend the investigation to other parts of the United States and of the world.

### INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE

Since the suspension of publication of the International Catalogue because of the inability of European countries to bear their share of its financial support following the World War, the United States bureau has made it a policy to spend only as much of the annual congressional appropriation as is needed to keep the organization alive pending the resumption of publication.

The report of the assistant in charge, Appendix 9, quotes from an article in Science by Dr. E. C. Richardson, who presents a strong case for the importance of revivifying the International Catalogue. His conclusions, in brief, are that the catalogue is an indispensable tool for research workers; that an organization which, if scrapped, would require a $3,000,000 endowment to build up again, is ready and waiting to resume the work of the catalogue when a very modest fund is made available to it; and that in the catalogue the research trust endowments will find an organization that can give the greatest bibliographical service to research for the least outlay of funds.

## NECROLOGY

### WILLIAM HOWARD TAFT

William Howard Taft, Chief Justice of the United States and Chancellor of the Board of Regents of the Smithsonian Institution, died in Washington on March 8, 1930. Of a man so prominently before the American public for so many years, it seems unnecessary here to present more than a very brief outline of his career.

Born in Cincinnati in 1857, Taft graduated from Yale University in 1878. He took the law course, and after a short period as law reporter for a newspaper, his public career began. In turn assistant prosecuting attorney, collector of internal revenue of the first district of Ohio, and assistant county solicitor of Hamilton County, he was next appointed judge of the Supreme Court of Cincinnati, and in 1890, Solicitor General of the United States. For eight years beginning 1892 he was United States circuit judge for the sixth judicial district, and in 1901, President McKinley appointed him civil governor of the Philippine Islands. In 1908 came his election as President of the United States, and after the completion of his term, there followed a few years of private life. In 1921 he was appointed Chief Justice of the Supreme Court, from which position he had been forced by ill health to resign only a short time before his death.

Through his many high offices, Mr. Taft had been connected with the Institution for many years, serving as a member of the Institution and its presiding officer, ex officio, and as Chancellor of its Board of Regents.

### GEORGE PERKINS MERRILL

George Perkins Merrill, head curator of geology, died suddenly in Auburn, Me., on August 15, 1929. Doctor Merrill was born in Auburn on May 31, 1854, and was graduated from the University of Maine with the degree of B. S. in 1879. He pursued advanced studies at Wesleyan and Johns Hopkins Universities which later resulted in the degrees of M. S. and Ph. D. from his alma mater. In 1893 he became professor of geology at Columbian, later George Washington University, continuing his lectures until 1916, and was given the honorary degree of Sc. D. in 1917.

Doctor Merrill's connection with the National Museum began with the organization of 1880. He served in various capacities in the geological division until 1897, when, under a reorganization, he was appointed head curator of the department of geology, which position he held until his death. The growth of the department from a comparatively few specimens, resulting chiefly from the United States Land Office and other early Government surveys, to its present position among the notable geological collections of the world, is largely due to Doctor Merrill's ability as an executive and his devotion and loyalty to the Institution. He was preeminently a museum man and an artist in methods of display, as can be attested by the harmonious arrangement of the exhibition halls under his charge.

Doctor Merrill early became interested in building stones and was regarded as the leading expert on this subject, his opinion being

sought in connection with such important structures as the Lincoln Memorial, the Washington Cathedral, and many other public buildings. His treatise on "Stones for Building and Decoration" ran to three editions.

Again, his researches on rock weathering and soil formation led an eminent authority to say: "The greatest work on the genesis of soils we owe to Merrill." A publication on "Non-Metallic Minerals—Their Occurrence and Uses" further illustrates his versatility in geological research.

Later, the collection of meteorites in the Museum became the object of special interest, his researches on these celestial bodies, resulting in no less than 60 papers, receiving recognition by the presentation of the J. Lawrence Smith medal of the National Academy of Sciences. "The Story of Meteorites," written in popular style, appeared as part 1 of volume 3 of the Smithsonian Scientific Series—"Minerals from Earth and Sky."

Among the most interesting and valuable of his many contributions is his historical work on geological subjects. His "contributions to a History of American Geology," published in 1904 as part of the report of the Smithsonian Institution, was, in 1924, expanded into "The First One Hundred Years of American Geology." He also compiled a "History of American State Geological and Natural History Surveys," issued as Bulletin 109 of the National Museum.

A paper for the Museum's archives, practically completed just before Doctor Merrill left on his vacation from which he never returned, is "An Historical Account of the Department of Geology in the U. S. National Museum"—most timely in its preparation since no other could have been so well qualified to prepare such a record.

### ARTHUR BENONI BAKER

Arthur Benoni Baker, assistant director of the National Zoological Park, died in Washington February 8, 1930. Mr. Baker was born at Otisco, New York, in 1858, and as a young man worked in Ward's natural science establishment. At that time Ward's, though a commercial institution, served as a training school for numerous young men who afterwards attained distinction in scientific work. With Mr. Baker were such men as Carl Akeley and William Morton Wheeler. Later Mr. Baker spent eight years fossil hunting in Kansas, and then in November, 1890, accepted a position in the National Zoological Park, where he served continuously until his death, except for a period of six months when he was on furlough and in charge of the Boston Zoological Garden.

In 1909 he made a trip to Nairobi, East Africa, and brought home a collection of animals that had been presented to the Zoo by Sir

Donald MacMillan through Theodore Roosevelt. On the trip out he made a hurried inspection of many zoological gardens in Europe and much of the information he gained there was used in the development of the National Zoological Park. Another expedition was to Porto Rico, where in company with other Smithsonian scientists he made valuable natural history collections.

It is largely due to the knowledge and devotion of Mr. Baker that the Zoological Park has attained its present position. His knowledge of zoos in general was profound; of the National Zoological Park, complete. He retained in his remarkable memory an almost unbelievable mass of detail.

Respectfully submitted.

C. G. ABBOT, *Secretary.*

# APPENDIX 1

## REPORT ON THE UNITED STATES NATIONAL MUSEUM

SIR: I have the honor to submit the following report on the condition and operations of the United States National Museum for the fiscal year ended June 30, 1930:

The total appropriations for the maintenance of the National Museum for this period amounted to $762,514, an increase of $14,490 over the appropriations for the year 1929. Of this amount $9,500 provided salaries for five additional positions on the staff, namely, an assistant curator of mollusks, an additional clerk in the administrative office, and three sergeants of the watch. This assistance in personnel has very definite value in the administration of the various units concerned and brings added efficiency to the organization as a whole.

A small sum of the increase indicated provided efficiency promotions for a number of trained mechanics who had not been cared for properly when other classes of employees had been promoted previously. There was a further increase to provide for the construction of a gallery to give additional space for study collections in the vertebrate paleontological laboratory, where crowding had become serious. The construction for this is of the same general type as that used for a similar gallery in the National Herbarium.

The second deficiency bill for 1930 contained an item of $3,500 under repairs and alterations of buildings, available in the fiscal years 1930 and 1931, for the remodelling of a comfort room in the Arts and Industries Building. As this bill became law on July 3, 1930, after the close of the fiscal year here under report, these funds accordingly will be used in the fiscal year 1931, and a statement on them will be made in the report for that year.

Growth in personnel in the National Museum has progressed reasonably, but further additions are required in a number of the administrative units before the staff can be considered properly developed to enable it to function as it should. There are several major groups of animals where systematic workers of high type are needed as curators to carry on necessary research that the Museum may be able to assist the public who desire information concerning the creatures in question. Additional assistance in the scientific grades is also required in some of the major groups where the volume

of work is beyond the capacity of the present staff to handle entirely adequately. Clerical assistance also is at a minimum, and there remain a considerable number of offices in which stenographic and clerical help is not at present available. Naturally this detracts from the efficiency of these offices since scientific workers who should be occupied otherwise are through necessity compelled to devote considerable time to routine work of a clerical nature. It is imperative that regular additions be made to our personnel to assist in these necessary functions. Further assistance is required in the shops, on the guard force, and in the labor force since it is at present necessary annually to obtain temporary workers in the groups concerned. The employment of temporary services, particularly where specialized work is concerned, is of doubtful expediency since necessarily part of the time is occupied in training, and there is more liability to error than with workers on a permanent basis.

Exploration and field work under the National Museum are financed largely by the Smithsonian Institution through its private income, and by friends who supply funds for various projects of particular interest. Existing appropriations for the National Museum are so largely taken up with routine expenditures that there is little available that may be used for research in the field. Further money should come from our appropriations for these ends.

Interest of the general public in scientific matters, particularly of the type that comes within the scope of the National Museum, is plainly evident through the demand that comes for popular exposition in scientific subjects. So far as the National Museum is concerned this interest is shown by the nearly 2,000,000 visitors who come annually to its halls. These persons, together with the many others who have an interest in such things, are among those who contribute to national income in the form of taxes. With their interest in these matters in mind it seems entirely logical that a part of their contributions should be devoted to furthering the development of the Museum which serves them in such various ways.

### ADDITIONS TO THE NATURAL HISTORY BUILDING

The Congress gave definite consideration during the year to the question of additional housing for the collections of the National Museum, with the result that the Smoot-Elliott bill authorizing the extension of the Natural History Building through wings at the east and west ends at a cost of $6,500,000 was passed without a dissenting vote. The bill was approved by the President on June 19, 1930.

Under this authorization it is planned to add to the present building so that it will extend from Ninth to Twelfth Streets on the same

width of base. In general it is contemplated that the style of the present structure will be duplicated, with the ground and third floor occupied by offices and laboratories, and the two intermediate floors devoted to exhibits. Present plans contemplate a request for funds for the preparation of definite architect's designs in the urgent deficiency bill for 1931. The friendly consideration given to the important matter of the authorization for this work by the congressional committees involved has been deeply appreciated by the Institution.

The construction planned will provide adequately for housing needs for the natural history collections. Following this, careful consideration should be given to proper space for the arts and industries series. The present building occupied by these collections, the old National Museum built in 1881, is now antiquated in design and unfitted for modern needs in museum exhibition. It should be replaced by a new structure that will provide ample halls for the showing of the important and valuable exhibits of the type mentioned.

The historical collections of the Nation, of interest and attraction to every patriotic American, at present are also in the old building. These collections, which are steadily growing with the accession of irreplaceable specimens, should be housed in a separate structure where such objects as the Star-Spangled Banner and the memorabilia of many famous men may be fittingly and attractively displayed.

## COLLECTIONS

Additions to the collections of the National Museum during the fiscal year have reached the total of 410,815 separate specimens, the greater part of these coming as in previous years to the department of biology. The additions, while not quite equal to those of last year, are of comparable value and importance to those of the last few years. Large donations have come from a number of sources, the museum as a governmental institution being recognized as a permanent organization in which valuable material will receive the care and attention that insure long preservation. The growing recognition of the National Museum as a repository of this kind is highly gratifying. Materials of various kinds sent in for examination and report during the year amounted to 1,306 lots, including many thousands of separate specimens. Gifts of duplicate materials made to schools and other educational institutions included 11,474 specimens, while in exchange with other scientific organizations and individuals there were sent out 12,649 specimens, these being duplicates for which return was made to the Museum collections. Loans to scientific workers outside of Washington included 33,208 specimens, many of which were of considerable value.

Following is a digest of the more important accessions for the year in the various departments and divisions of the Museum:

*Anthropology.*—Collections from Alaska again are of major importance among the accessions in this department. Among these there are two principal lots of material that have come in part through the assistance of the Smithsonian Institution. Doctor Hrdlička in travel down the Yukon River obtained rich collections representing Indian and Eskimoan tribes, and in addition obtained valuable sets of ivory implements from the Bering Sea area. Henry B. Collins, jr., in further field work on St. Lawrence Island and sites on the coast of Bering Sea and Kotzebue Sound secured a collection containing many ivory and other implements that are of great value in supplementing his collections of last year. Further there was obtained by purchase a series of specimens from Point Hope representing various phases of Eskimoan culture. The entire lot represents a selection of western Eskimoan artifacts from the earliest times, still further increasing the value of our excellent series of this kind.

A further collection from Nigeria and the Gold and Ivory coasts of Africa presented by C. C. Roberts has supplemented previous gifts of a similar nature from the same source, until now we have for the first time adequate representation of the Haussa, Fulah, and Yoruba tribes.

The Department of Agriculture, through Dr. E. W. Brandes of the Bureau of Plant Industry, transferred excellent collections of stone axes, decorated human heads, and other objects from New Guinea.

Collections from Tibet were presented by Charles S. Isham, of New York, including prayer stones and other objects of a religious nature, as well as materials of personal adornment. Further collections have come from China through the efforts of the Rev. D. C. Graham, of Szechwan.

In American archeology there came three decorated limestone blocks from the Maya Temple of Chac Mool, deposited by the Republic of Mexico through its Secretaria de Educacion. Valuable specimens were obtained from the excavations in Colorado of Dr. Frank H. H. Roberts, jr., of the Bureau of American Ethnology, and from field work by H. W. Krieger, of the National Museum, in the Dominican Republic, funds for this project having been furnished by Dr. W. L. Abbott.

Through the Bruce Hughes fund there were acquired artifacts of Sumerian and Babylonian origin for exhibition with other materials from the Old World.

*Biology.*—In the department of biology there were secured extensive collections as a gift of the National Geographic Society, including particularly birds and plants collected by Dr. Joseph F. Rock

in western China, and birds, insects, and plants obtained by E. G. Holt in northern Brazil. Other excellent collections came from the Hon. Gifford Pinchot as the result of a cruise to the Caribbean and Pacific Islands on the yacht *Mary Pinchot*. A notable collection obtained through the cooperation of the Navy Department was secured by Dr. H. C. Kellers, United States Navy, on the Island of Panay, in the Philippines, during service as medical officer to the Naval Solar Eclipse Expedition.

Doctor Bartsch, traveling under the Walter Rathbone Bacon Travelling Scholarship, obtained large series of mollusks in the West Indies, which add remarkably to our collections from that region. Dr. G. A. MacCallum, of Baltimore, presented his entire collection of helminthological material, including many type specimens.

Collections forwarded by the Rev. D. C. Graham from western China include many things of great value, particularly among mammals, birds, fishes, reptiles, and insects. There may be mentioned especially three skins of the giant Panda.

Further excellent collections from Siam were received from Dr. Hugh M. Smith, long an honorary associate of the Institution.

A. C. Bent, a collaborator of the Smithsonian Institution, deposited in the division of birds his collection of North American birds' eggs, a most excellent and complete series. From the Minneapolis Public Library there were obtained more than 1,500 bird skins from the Philippines comprising the Menage collection. The Smithsonian-Parish expedition to Haiti obtained excellent series of birds, reptiles, and other materials. Under the Swales fund, through money left by the late Bradshaw H. Swales, there were secured 34 skins of birds new to the Museum.

The Victorias Milling Co. of Manila presented a considerable number of insects collected by Dr. W. Dwight Pierce. For the division of mollusks there were purchased series of land shells from Jamaica and Haiti through the Chamberlain fund. Through a botanical expedition to Peru and Upper Brazil under E. P. Killip there were acquired more than 27,000 specimens of plants.

*Geology.*—In the department of geology the single accession of greatest importance during the year was the crystal ball presented to the National Museum by Mrs. Worcester Reed Warner as a memorial to her husband, long a friend to the Smithsonian Institution. This ball of flawless crystal 12⅞ inches in diameter, weighing 106¾ pounds, is believed to be the largest perfect sphere of its kind in existence. It is one of the most striking objects found in the Museum halls.

Through the income of the Roebling fund there have been secured 23 species of minerals not previously represented in our collections,

together with a considerable number of exceptionally fine specimens of other kinds. Among them there may be mentioned a topaz crystal weighing over 7 pounds, sets of tourmaline crystals, and a cut yellow sapphire of 25.8 carats.

Through the Frances Lea Chamberlain fund there were secured blue and yellow diamonds, a Brazilian emerald, and carvings of jade, tourmaline, coral, amber, carnelian and lapis-lazuli.

Valuable specimens of ores and stones have come from several sources. Numerous type specimens have been accessioned in the division of stratigraphic paleontology, particularly fossil plants described by Prof. E. W. Berry. Further fossil plants from the Grand Canyon of the Colorado in Arizona, collected and described by Dr. David White, have been presented by the Carnegie Institution of Washington.

A collection of several hundred fossils from English localities secured by Mr. B. B. Bancroft has come as a deposit from the Smithsonian Institution. Other valuable specimens secured in field work by Dr. Resser have included more than 1,200 Cambrian forms.

Eight articulated skeletons of the fossil horse *Mesohippus bairdi* from the Oligocene of Nebraska were purchased. Large series of excellent fossil horse skulls have come also from the field work of Dr. Gidley in Idaho. Valuable material collected by Mr. C. W. Gilmore in the San Juan Basin, N. Mex., has come to the fossil reptile collection through work financed by the Smithsonian Institution.

Dr. Remington Kellogg and N. H. Boss collecting in Alabama and Mississippi under the auspices of the Carnegie Institution of Washington secured a valuable specimen of zeuglodont, together with other material. There may be mentioned also a complete skull and other bones of a large whalebone whale collected by Dr. Kellogg at Governors Run, Md.

*Arts and industries.*—The gift of the Rudolph Eickemeyer collection of photographs and books to the section of photography constituted one of the most important accessions to this department, as it includes not only an excellent series of pictorial photographs but also a library of books dealing with this subject, and a series of medals and awards made to Mr. Eickemeyer for the excellence of his work. The gift is further accompanied by an item in the will of Mr. Eickemeyer through which $15,000 is designated as a fund to be used in connection with this collection.

The collection of Edward Goodrich Acheson memorabilia, recording the researches of this worker, presented by the Acheson Oildag Co., has given important historical material, as has also a collection

of drawings and documents and other things relating to the industrial development of the steam boiler presented by the Babcock and Wilcox Co., of New York City, through its President, A. G. Pratt.

A series of 21 airplane propellers was presented by the American Propeller Co. The United States Coast and Geodetic Survey transferred 26 specimens of early surveying and navigation instruments, including examples 50 to 75 years old.

The family of Leander James McCormick through Robert Hall McCormick presented eight models of labor-saving farm machinery invented and constructed between 1829 and 1835 by Robert McCormick, of Walnut Grove, Va. These include early types of the McCormick reaper.

Many specimens of scientific value added to the study collections of woods include a series of 598 woods from various parts of the world.

To the division of graphic arts there came 1,210 prints as a gift from J. Townsend Russell, jr., including the work of many important engravers. The Eastman Kodak Co. presented a number of items to the section of photographic apparatus.

*History.*—Silverware formerly owned by Thomas McKean, one of the signers of the Declaration of Independence, presented by Mrs. Frances T. Redwood, and five pieces of chinaware used in the White House by President James Madison, presented by Miss Mary M. McGuire, are among the important accessions in this division.

To the costumes collection there came a rose chiffon velvet gown worn by Mrs. Coolidge, on the occasion of the last formal reception in the White House during the administration of her husband, President Calvin Coolidge. The gown was presented to the Museum by Mrs. Coolidge.

An item of importance added to the military collections was a set of uniforms and accessories of the type worn during the World War and subsequently by officers and enlisted men of the Turkish Army. This material was presented by the Government of Turkey through Ahmet Mouhtar Bey, Turkish Ambassador to the United States.

A considerable series of specimens came as a deposit to the numismatic collections from the American Numismatic Association, including recent coinages of many countries. The Bureau of the Mint of the Treasury Department transferred a number of ancient and modern coins of importance.

The philatelic collection received a large number of specimen stamps from the Post Office Department, as well as a special collection of Chinese stamps presented by the Hon. Liu Shu-fan, Director General of Posts of China.

## EXPLORATIONS AND FIELD WORK

Researches in the field have been carried on as usual by various members of the scientific staff of the Museum, principally by means of funds provided by the Smithsonian Institution through its private income, with assistance in some instances in the form of contributions from friends of the organization who have been interested in different projects. Certain investigations have been financed also under some of the specific funds of the Smithsonian. For some expeditions small allotments have been made from the annual appropriations, but these constituted only a small part of the total expenditure for field work, by far the greater portion having come from other sources. An additional appropriation that could be used for field researches is a definite need of the National Museum, and would be of great assistance in promoting its work. A brief account of field work for the present year follows:

During the months of December and January, Henry B. Collins, jr., assistant curator in the division of ethnology, conducted field work in Mississippi, the investigations being carried on in cooperation with the Mississippi Department of Archives and History, that organization being represented by Messrs. Moreau B. Chambers and James A. Ford. The most important result was the finding in Yazoo County of an ancient Indian village site in which the complete floor plan of a large house site was traced by means of the postholes. The structure was round, 60 feet in diameter, and was probably a council house somewhat similar to those described by early explorers in the Creek and Cherokee regions. The opening of the fiscal year in July found Mr. Collins in the field excavating at old Eskimo sites on St. Lawrence Island in Bering Sea, and along the coast of Kotzebue Sound in western Alaska. His work included a reconnaissance of the western Alaskan coast from Norton Sound to Point Hope. Actual excavations were carried on at Cape Kialegak on St. Lawrence, Cape Denbigh, Imaruk Basin, and Point Hope, resulting in a large archeological collection. Work on St. Lawrence Island was begun again in June, 1930, with most important results as indicated by preliminary reports from the field. The National Museum is deeply indebted to the Revenue Cutter Service for its active cooperation in these investigations through transportation provided on its vessels to points otherwise inaccessible.

Field work in the Dominican Republic was continued by Herbert W. Krieger, curator in the division of ethnology, who began archeological and historical studies in that area in 1928. Mr. Krieger's investigations were made possible by the assistance of Dr. W. L. Abbott, whose interest in the island is of long standing and whose

first visit to Santo Domingo was in 1883. Investigations during the current year included a reconnaissance of the mountainous interior of the provinces of La Vega, and of Azua, and actual excavations at former Indian village sites in the valley of Constanza and on the Caribbean coast at Andres, on the Bay of Andres, 25 miles east of the capital city of Santo Domingo. There was no noteworthy distinction between the artifacts recovered from middens at Constanza and at Andres except for the lack of marine products such as bones of fish and turtles, and shells of mollusks in the middens of the central mountains. Shell deposits on the Caribbean coast resemble those found in caves in the province of Samaná, and also those included in the kitchen middens of Monte Cristi Province. Middens throughout the Dominican Republic yield typically Arawakan objects of great variety, ranging from the petaloid polished stone celt, decorated pottery with incised and punctate designs, and molded figurine heads of post-archaic type, to the beveled celt of *Strombus gigas*, shallow undecorated earthenware bowls, crude beads of shell with hour-glass-shape perforation, and other artifacts that in Cuba have been designated as products of the "Ciboney." Frontal-occipital deformation of skulls from cemeteries, fragments of stone collars, and well-known types of Arawak zemis supply additional evidence of the thorough penetration of the island by the Arawak and conversely tend to stress the lack of cultural stratigraphy or evidence of the previous occupancy of the island by pre-Arawak tribes.

From May 15 to September 23, 1929, N. M. Judd, curator of American archeology, was in Arizona supervising the Third Beam Expedition of the National Geographic Society. As a result of these investigations, Dr. A. E. Douglass, of the University of Arizona, was able to complete his tree-ring chronology by establishing a single series of annual growth rings in pine trees, extending from the year 1929 back to 700 A. D. Thus, with over 1,200 years represented, some 40 pre-Spanish Pueblo villages of the Southwest have been correlated with our own calendar—certainly the most outstanding contribution to American archeology in the past quarter century. Following his researches for the National Geographic Society, the curator, at the suggestion of Senator Carl Hayden, visited the Gila and Salt River valleys, Ariz., to examine remaining vestiges of a former network of prehistoric canals and to determine the most feasible means of preserving a permanent record of them. On behalf of the Bureau of American Ethnology, Mr. Judd returned to Arizona in mid-January to cooperate with Lieut. Edwin B. Bobzien and Sergt. R. A. Stockwell, of the Army photographic personnel, in an aerial survey of the major prehistoric canal systems bordering both the Gila and Salt Rivers. The mosaic photographic maps made from

the air resulting from this survey, though not yet completely studied, indicate results of importance.

Doctor Hrdlička, curator of physical anthropology, during the summer of 1929 made his second expedition to Alaska. The work of the present season covered the Yukon from White Horse to Fort Yukon as a reconnoissance, and from Fort Yukon downward continued as an intensive exploration in abandoned and partly washed-away village sites, resulting in valuable collections of skeletal remains and archeological implements. Physical measurements were made on several hundred living natives, some of them the last representatives of their tribes, and facial casts and hundreds of photographs were taken.

Dr. Paul Bartsch, through the Walter Rathbone Bacon Travelling Scholarship of the Smithsonian Institution, continued this season the exploration of West Indian Islands for the study of their terrestrial molluscan fauna, a work begun last year. He left Norfolk, Va., in June, 1929, for Porto Rico, where at San Juan a schooner, the *Guillermito*, was chartered. Doctor Bartsch was accompanied by Dr. William W. Hoffman and his assistant, J. Oliver, who were engaged in other biological studies. The work began in Porto Rico and then continued to Culebra and St. Thomas. On July 14 the party visited the island of St. John and on the 15th St. Croix. Stops were next made at Tortola, San Martin, Anguilla, San Bartholomew, St. Eustatius, St. Cristopher, Nevis, Montserrat, and Grande Terre. On July 31 they had reached Guadeloupe, and August 1 and 2 were on the Saints. They next visited Maria Galante and Dominica, and August 7 and 8 were at Martinique. This was followed by exploration of Santa Lucia, St. Vincent, and on August 17 of the Grenadine islets. The expedition arrived at Grenada on August 25 and remained there until the 28th. September 1 to 4 were spent on Trinidad. Margarita Island, off the Venezuelan coast was visited September 7 and 8, followed by stops at Orchilla, El Roque, Bonaire, Curacao, and Aruba. On September 24 the party arrived once more at San Juan, Porto Rico. In addition to a rich harvest of mollusks, this expedition as a by-product secured numerous specimens of animals of many groups as detailed elsewhere in this report.

Rev. David C. Graham, long a cooperator in the field work of the Smithsonian, in the summer of 1929 made a collecting expedition to the Mupin district in Szechwan, the type locality of many of the species discovered by the Abbé Armand David. Doctor Graham started from his headquarters at Suifu on June 15 and reached Mupin 11 days later. He made collections at several localities in the district with good results, obtaining numerous specimens of mammals, among them three flat skins of the "giant panda," birds, reptiles, amphibians, fishes, and insects. He returned in August to

Suifu, characterizing the trip as a successful reconnoissance. A number of forms in the different groups enumerated are new to the Museum, and the entire collection is of great importance.

Through the cooperation of Mr. Lee Parish, of Tulsa, Okla., there was organized in the late winter the Parish-Smithsonian expedition to Haiti, on which Mr. Parish, and Mr. and Mrs. S. W. Parish were accompanied by Mr. W. M. Perrygo of the taxidermy staff. The party sailed from Miami, Fla., on February 15, on the yacht *Esperanza*, passing along the north coast of Cuba, where stops for collecting were made at Gebara, Moa Key, the mainland opposite Moa, and Port Tanamo. In Haiti visits were made to Gonave and Petit Gonave Islands, both north and south sides of the southern peninsula, Ile-à-Vache off the south coast, and Navassa Island. Mr. Perrygo returned by steamer from Port-au-Prince, Haiti, on May 28, arriving in New York June 2. The specimens brought back include 35 mammals, about 600 birds, 206 reptiles, 281 fish, marine invertebrates, and echinoderms, as well as some live animals for the National Zoological Park. The material is of importance and will give much information of value concerning the area covered.

The Museum has also had the valued cooperation of the Hon. Gifford Pinchot in the Pinchot South Sea Expedition which sailed from Brooklyn, N. Y., on March 30, 1929, in the auxiliary yacht, *Mary Pinchot*. The party consisted of the Hon. Gifford Pinchot, Mrs. Pinchot, Dr. H. A. Pilsbry of the Philadelphia Academy of Natural Sciences, and Dr. A. K. Fisher of the Biological Survey, Department of Agriculture, who through cooperation of the survey was detailed to make collections for the National Museum. No stops were made until Key West was reached on April 7, when four days were spent at this interesting place. A short stop was made at Habana, whence the expedition proceeded to Grand Cayman Island. On April 16 and 17 a collection of birds and other zoological specimens was made there, and the party then continued to Swan, Old Providence, and St. Andrews Islands. A hummingbird new to science was taken on the island of St. Andrews. Cristobal, in the Canal Zone, was reached on April 29 and on account of engine trouble the expedition was detained for the following month in the Canal Zone. On June 1 the *Mary Pinchot* left Balboa for Cocos Island, where several days were spent collecting specimens. They continued to the Galapagos Islands on June 11. The first stop was made at Tower Island, followed by visits to Indefatigable, Seymour, Charles, Hood, Chatham, Barrington, Albemarle, Narborough, and a number of smaller islands. Considerable collections of birds and other zoological material were obtained by August 26, when the party continued westward. At Tagus Cove, Albemarle Island, the flightless cormorant and penguin were found. From the Galapagos

Islands the expedition proceeded 3,100 miles to the Marquesas Islands, where they visited Hiva-oa, Fatu-Hiva, Uahuka, Nukahiva, and later Eiao, one of the islands of the northern group. From this point the voyage continued to the Tuamotu Islands. Fruit pigeons, robber crabs and other crustaceans, corals, and shells were collected. The cruise was ended at Papeete, Tahiti; because of the lateness of the season the party returned by steamer to San Francisco, arriving there on October 25, 1929. The *Mary Pinchot* was taken back to Savannah, Ga., by the officers and crew.

Through the untiring energy of Mr. Pinchot and of Doctor Fisher, who represented the Museum on the expedition, large and valuable collections including porpoises, bats, birds, reptiles, fishes, insects, and other animals have come to the Museum as noted elsewhere in this report, numerous forms being new to our collections.

The explorations of Dr. Hugh M. Smith in Siam were continued throughout the year. Among other journeys he made a trip to the mountains of northern and northeastern Siam, where little zoological collecting has been done before. As in previous years a number of species new to science have been obtained.

In May, 1930, Doctor Wetmore made a short collecting trip principally for birds in the mountains of northern Spain, where he obtained a number of forms new to the Museum collections. His work was carried out principally from Puente de los Fierros, Busdongo, and Riaño.

Dr. Joseph F. Rock continued work, under the auspices of the National Geographic Society, in the semi-independent kingdom of Muli, in southwestern Szechwan, China, and also visited the Minyakonka Mountains. He made important collections of birds and plants, the specimens coming to the National Museum as a gift from the National Geographic Society.

Mr. Ernest G. Holt, traveling under the auspices of the National Geographic Society, accompanied a boundary survey party along the Venezuelan-Brazilian frontier, returning to this country with a valuable collection of birds, reptiles, plants, and other material which was presented to the National Museum by the National Geographic Society.

Dr. H. C. Kellers, United States Navy, who through cooperation of the Navy Department was attached as surgeon to the Solar Eclipse Expedition to the island of Panay, P. I., returned with large zoological collections, principally of reptiles, fishes, and marine invertebrates, which are of great scientific value.

Dr. J. M. Aldrich was in Europe at the beginning of the fiscal year examining types of species of flies in the British Museum. In July he proceeded to Bergen, Norway, and after a brief collecting excursion there continued to Sweden, where he spent a successful season

collecting at Åre. During this work he ascended the Åreskutan, a mountain 5,000 feet high, where Zetterstedt, 100 years before, had made important entomological collections.

Doctor Aldrich left Washington on May 15, 1930, for a collecting trip to the high altitudes of Idaho, Washington, Oregon, and northern California, a journey on which he was absent at the end of the fiscal year.

Mr. H. H. Shamel, of the division of mammals, was detailed for about three weeks in May, 1930, to collect natural history specimens in southwestern Missouri and eastern Kansas. Twenty days were spent in Barry and McDonald Counties, Mo., and a few days in Montgomery and Harvey Counties, Kans. The collection obtained included 65 mammals, 399 fishes, 34 birds, and between 100 and 125 reptiles, invertebrates, and insects, as well as three living mammals for the National Zoological Park. The black-tailed jack rabbit obtained in Barry County, Mo., was of interest as it is said to have been in this region for only about 20 years, though previously recorded for Missouri from Vernon County.

E. D. Reid, of the division of fishes, was detailed from March 20 to April 12, 1930, to make collections of fresh-water animals in the highlands of North Carolina, Tennessee, and Georgia. He secured a fine lot of amphibians.

E. P. Killip, associate curator of plants, accompanied by Mr. Albert C. Smith and Mr. W. J. Dennis, made an extended journey to eastern Peru and Amazonian Brazil, remaining in the field from April 9, 1929, to November 15, 1929. The expedition, under the Smithsonian Institution, made general botanical collections and investigated especially the various plants used as fish poisons. The New York Botanical Garden cooperated in the project by allowing Mr. Smith, a member of the Garden staff, leave of absence for the work. Nearly 27,000 specimens were collected, and such studies as have been made to date show that a large number of novelties were obtained. Many species have never before been brought back to American herbaria.

Dr. A. S. Hitchcock, custodian of the grass herbarium, spent the months from July to October, 1929, in South and East Africa, collecting and studying grasses. He visited Cape Colony, Transvaal, Portuguese East Africa, Tanganyika, Zanzibar, Kenya, and Uganda, obtaining a large number of specimens. He was an officially invited guest of the British Association for the Advancement of Science meeting in South Africa.

Mrs. Agnes Chase, of the grass herbarium, made an expedition to Brazil during the months October to May, visiting the States of Rio de Janeiro, Espirito Santo, Minas Geraes, Goyaz, Sao Paulo, and

Mattogrosso. More than 2,500 collection numbers were obtained, with an average of five specimens to each number.

For four months of the last fiscal year and extending into the early part of this, Dr. W. F. Foshag was engaged in field work in the borax regions of California, Nevada, and Oregon, collecting under the Roebling fund of the Smithsonian Institution with the collaboration of the Harvard Mineralogical Museum. The purposes of the expedition were to study the mineralogy and geology of the borax deposits, with particular regard to their origin, and to obtain for the Museum a comprehensive collection of typical minerals and ores. It was thought desirable to undertake the work at this time since changes in the borax industry have rendered obsolete many of the most interesting of the deposits. Some very fine exhibition specimens, a comprehensive series illustrating the geology and mineralogy of the deposits, and much duplicate material resulted.

In the latter part of April Doctor Foshag was detailed to examine some mineral localities in North Carolina. Through the courtesy of Messrs. Burnham S. Colburn and Will Colburn of Biltmore Forest, he was enabled to visit Spruce Pine, Balsam Gap, Mason's Mountain, Webster, and Statesville, and to collect rare uranium and other minerals.

In order to carry out an expressed wish of the late Dr. Frank Springer, Dr. R. S. Bassler visited Europe for the purpose of making casts of various type specimens of crinoids preserved in foreign museums. His chief object was to obtain facsimiles of the specimens described by Barrande, which, with many other mementoes of that famous paleontologist, are preserved in the National Museum at Prague, Bohemia, this having been the scene of his greatest work. Under most pleasant conditions and with the hearty cooperation of the authorities at the museum, this work was carried to a successful conclusion. Doctor Bassler was also enabled to visit other European museums and various collecting fields. At the museums the paleontological collections were studied and personal contact established with the authorities; the time at the collecting fields was devoted mainly to a study of the stratigraphy, in order to secure data for the furtherance of work on our collections.

Late in the year, Doctor Bassler, accompanied by Dr. Ferdinand Canu, made brief field trips in New England and along the Atlantic coast in furtherance of their studies on Bryozoa.

Dr. C. E. Resser continued researches on the Cambrian of the Rocky Mountain region under the Smithsonian Institution. For a portion of the time he was accompanied by Dr. L. J. Moraes of the Brazilian Geological Survey, who was interested in similar problems. Doctor Resser's chosen field was in Montana, with a stop in the Yellowstone National Park to examine certain peculiar

structures caused by algal deposits. Camp was next established on the Bridger Range in Montana, where a restudy of the stratigraphy proved it to be much more complicated than was previously supposed. Thence a move westward and northwestward led into the Blackfoot country where the pre-Cambrian and Cambrian rocks were examined. Following this various ranges in southwestern Montana were visited, and the last part of the season was spent in the Teton Mountains in extending the studies of the previous season. Small collections were made, the expedition being devoted mainly to field observations.

The field expedition under the Smithsonian in charge of Mr. C. W. Gilmore covered certain badland areas extending from Kimbetoh northward to Farmington in the San Juan Basin, N. Mex. Although the surface indications gave every promise of yielding rich returns, it was found that the majority of the leads consisted of single bones. Individual skeletons had evidently been widely scattered before interment, and only occasionally were portions of skeletons found together, which fact, however, did not prevent the collecting of material of much scientific interest, as several news species appear to be represented and some known forms are new to the fauna. The collection, as a whole, is a decided contribution to the meagerly known faunas of the area.

The expedition under the Smithsonian by Dr. J. W. Gidley to the Snake River Valley, Idaho, inaugurated toward the end of the last fiscal year, was attended with unusual success—so much so, in fact, that a second expedition to the same region is now in progress. Well preserved remains of a rare extinct species of horse comprise the most important part of the collection, while gravel deposits in the vicinity yielded a large species of bison, a giant muskox, camel, horse, and other extinct animals of the Pleistocene period.

Later in the year Doctor Gidley continued his researches dealing with the problem of the association of early man with the extinct mammalian fauna in Florida, the work being financed by contributions from Mr. Childs Frick and by the Smithsonian. Worth-while data and material were obtained, though the expedition was greatly hindered by excessive rains which rendered it impossible to work out some of the most promising localities.

Under the auspices of the Carnegie Institution of Washington, Dr. Remington Kellogg, assisted by Mr. Norman Boss, was occupied for a month in exploration of the Eocene (Jackson) deposits in Alabama and Mississippi for zeuglodont remains. The resulting small collection of these comparatively rare fossils was presented to the Museum. Messrs. Kellogg and Boss also made one trip of three days to the near-by Miocene localities along Chesapeake Bay to collect cetacean remains.

In August members of the Maryland Geological Survey brought to the Museum's attention the discovery of a large whalebone whale skull located in Miocene deposits in the vicinity of Governors Run, Md. Dr. Remington Kellogg, with the assistance of Mr. A. J. Poole and members of the Maryland Survey staff, were successful in collecting it, the specimen being one of the first of this type discovered.

Late in the fiscal year Mr. C. W. Gilmore was detailed to head an expedition into the Eocene of the Bridger Basin in southwestern Wyoming, and Dr. J. W. Gidley returned to the scene of his 1929 collections in Idaho. As both expeditions will continue well into next year, detailed accounts will go over until the next annual report.

### BUILDINGS AND EQUIPMENT

The usual routine repairs have kept the buildings of the National Museum in proper condition. At the beginning of the year the work of safeguarding the dome of the Natural History Building had just been finished. Before opening the rotunda to the public the walls were steam-cleaned, the plastered surfaces repainted, and the floor repolished. The rotunda was opened finally on October 23, 1929, after having been closed to visitors for nearly two years. Walls and ceilings in the north entrance to the Natural History Building, as well as various exhibition, office, and laboratory rooms, were repainted. The roadways on the east and west sides of the buildings were closed by gates to prevent their use as thoroughfares by unauthorized vehicles; this step was taken because of several accidents that had taken place there. With the assistance of the office of Public Buildings and Public Parks, a steel gallery was erected in the storage rooms of the division of vertebrate paleontology to provide additional space for the storing of fossils.

In the Arts and Industries Building the fountain in the center rotunda was removed because in recent months several visitors intent on other matters had stumbled over the coping and fallen into the water. Roofs and exterior woodwork were repainted, and various rooms and offices were redecorated. Work in enlarging the women's rest room was begun, a special item of $3,500 toward this project being included in the second deficiency act approved after the close of the year.

The power plant was in operation from September 27, 1929, to May 28, 1930. The consumption of coal was 3,502 tons, an amount in excess of that burned during the previous fiscal year. The average cost was $5.65 per ton. The Steamboat Inspection Service examined the boilers during the year and made certain suggestions as to their condition. The elevators have been regularly inspected by the District of Columbia inspector. The total electric current produced amounted to 655,253 kilowatt-hours, manufactured at a

cost of 1.78 cents per kilowatt-hour, including interest on the plant, depreciation, repairs, and material. The amount of electric current produced represents an increase of approximately 6,500 kilowatt-hours over that of last year, and the plant is now operating at its maximum capacity. As demands for electric current increase steadily it will be necessary during the coming fiscal year to purchase a limited amount from the local company during the winter season, in addition to the regular purchase made during the summer season when the Museum plant is not in operation.

The ice plant manufactured 435.5 tons of ice at the average cost of $1.71 per ton; this cost represents a definite reduction over that for the previous year.

During the year 7 exhibition cases and bases, 308 pieces of storage, laboratory, and other furniture, and 2,224 drawers of various kinds were added, the greater part of these being manufactured in our shops.

### MEETINGS AND RECEPTIONS

The lecture rooms and auditorium of the National Museum were used during the present year for 135 meetings covering the usual wide range of activities. Government agencies that utilized these facilities for hearings, meetings, lectures, and other special occasions included the Bureau of Chemistry and Soils, the Forest Service, the Graduate School, Food, Drug and Insecticide Administration, the Extension Service of the United States Department of Agriculture, and the United States Public Health Service. The Graduate School and the Forest Service of the Department of Agriculture arranged a series of addresses during the year on various matters concerned with their work. Scientific societies that met regularly in the auditorium or small lecture room included the Vivarium Society, the Entomological Society of Washington, the Society for Philosophical Inquiry, the Anthropological Society of Washington, and the Helminthological Society of Washington. Meetings were held also by the Washington Academy of Sciences, the Wild Flower Preservation Society, the Potomac Garden Club, the Twentieth Century Club and Federation of Women's Clubs, the Washington Society of Engineers, and the Washington Glider Club. The National Association of Retired Federal Employees held regular meetings through the year, as did groups of high schools for special addresses.

On December 26 Dr. Heinrich Reis of Cornell University, retiring president of the Geological Society of America, delivered an address in the auditorium. A series of special meetings was held by the Anthropological Society for lectures by Dr. Fay-Cooper Cole on

January 7, on January 21 by Dr. Aleš Hrdlička, on February 4 by Dr. Clark Wissler, on February 18 by Dr. Herbert J. Spinden, and on March 4 by Mr. Neil M. Judd. On January 14 Dr. Hrdlička delivered an address on Organic Evolution before the Washington Academy of Sciences, and on February 20, Prof. E. W. Berry of Johns Hopkins University spoke before the same organization on the Origin and Evolution of Plants. On April 16 Dr. Charles B. Davenport of the Carnegie Institution of Washington lectured on the Mechanism of Organic Evolution.

The Food Standards Committee of the Food, Drug, and Insecticide Administration, United States Department of Agriculture, held a public hearing on April 30 in room 43. On January 15 the Maryland-Virginia Farmers' Marketing Association held a business meeting in the auditorium. The seventh National and fifth International Oratorical Contest for the Evening Star area was held in the auditorium on May 8, with J. Loren Freund of Gonzaga College, Miss Virginia Carr, of Oakton High School, Va., and Miss Frances Gertrude McKim, St. Mary's Seminary, St. Mary's City, Md., as speakers. On May 27 the sixth annual National Spelling Bee was held in the auditorium. From June 18 to 20 the United States Public Health Service held a conference with State and Territorial health officers in room 43. Addresses were made by Dr. Ray Lyman Wilbur, Secretary of the Interior, Surg. Gen. H. S. Cumming, and others.

From June 18 to 24 the meeting rooms were used by the Extension Service of the United States Department of Agriculture for conferences in connection with the 4-H Club camp.

A memorial meeting was held August 16 to commemorate the service to science of the late Dr. George P. Merrill, head curator of geology of the United States National Museum.

On the evening of December 10 the formal opening of the exhibition of paintings purchased under the Henry Ward Ranger bequest was held in the National Gallery of Art from 9 to 11. The District of Columbia section of the Woman's Auxiliary to the American Institute of Mining and Metallurgical Engineers arranged a reception in the National Gallery rooms on December 26 for ladies in attendance at the meetings of the Geological Society of America.

### MISCELLANEOUS

The exhibition halls of the National Museum were open during the year on week days from 9 a. m. to 4.30 p. m. and with the exception of the aircraft building were open Sunday afternoons from 1.30 to 4.30; all museum buildings remained closed on December 24 and 25, in accordance with presidential order, and were closed also on New Year's Day.

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The flags on the Smithsonian and Museum buildings were placed at half mast on November 19, 1929, out of respect to the late James Wilson Good, Secretary of War. They were flown at half mast from March 9 to April 7, 1930, out of respect to ex-President William Howard Taft, associated for many years with the Smithsonian Institution as a member of the Institution, presiding officer ex officio, Regent, and Chancellor. On November 13 the flag pole on the Smithsonian building was found to be in a dangerous condition and was removed so that no flag was flown on that building until April 10, 1930, when a new pole was put in place on the north tower.

Visitors to the Museum during the year totaled 1,894,989, a decrease of approximately 35,000 from the record of the preceding year. This decrease apparently reflected changed economic conditions in the country. Attendance in the several buildings of the National Museum was recorded as follows: Smithsonian Institution, 282,482; Arts and Industries, 863,479; Natural History, 625,326; Aircraft, 123,700. The average daily attendance for week days was 5,125, and for Sundays 10,317. The increase in the Sunday average of nearly 4,000 persons per day is a certain indication of the need for opening the exhibits to the public on Sunday afternoons.

During the year the Museum published 16 separate volumes and 35 miscellaneous papers, while the distribution of literature amounted to 87,323 copies of its various books and pamphlets. Additions to the Museum library included 2,317 volumes and 668 pamphlets, obtained partly by exchange, partly by donation, and partly by purchase. The library of the National Museum as separate from that of the Smithsonian Institution proper now contains 76,879 volumes and 108,297 pamphlets. Much work was done in arranging the catalogues of these collections. The Museum has 36 sectional libraries in connection with its various divisions, each containing the particular books relating to the work involved. These are in addition to the main libraries that house the works of general reference.

On October 1, 1929, Dr. R. S. Bassler was made head curator of the department of geology. Dr. Charles E. Resser was designated on December 1 curator of stratigraphic paleontology. Dr. W. F. Foshag was made curator of the division of mineralogy and petrology on September 1, and in addition was given charge of the work of the division of physical and chemical geology. Mr. Edward P. Henderson was appointed on November 16 assistant curator in the division last mentioned.

Dr. Charles W. Richmond, long associate curator in the division of birds, was given the title of curator on July 1. On September 16 at Dr. Richmond's own request he again became associate curator

and Dr. Herbert Friedmann was appointed curator. The division of ethnology was reorganized during the year, with resulting change in status for H. W. Krieger, curator, and H. B. Collins, jr., assistant curator. Julian S. Warmbath was appointed taxidermist on October 1. Wm. H. Egberts was given the title of chief preparator of the department of anthropology, and Norman H. Boss that of chief preparator in vertebrate paleontology. Miss Leila G. Forbes was appointed assistant librarian to succeed Miss Isabel L. Towner, who resigned on September 7. Miss Gertrude L. Woodin succeeded Miss Ethel A. L. Lacy, chief of the accessions department, who severed her connection with the Museum on September 15. On July 1 Mrs. Florence L. Grock was appointed principal accounting and auditing assistant. Michael Cahillane, Clarence R. Kyte, and William H. Smith were appointed sergeants July 1. On August 16 Mr. Cahillane was advanced to lieutenant, and Wm. H. Vanneman was made sergeant on September 1.

Three employees left the service through the operation of the retirement act—Edgar W. Hanvey, cabinet-maker, after a service of nearly 32 years; A. C. Dufresne, lieutenant of the watch, after 18 years on the guard force; and Carl A. Ohlson after nearly 18 years' service as watchman. The Museum lost through death during the year seven of its active workers and one member of its honorary scientific staff. Dr. George P. Merrill, head curator of geology, died August 15, 1929. Dr. Jesse Walter Fewkes, collaborator in ethnology, died on May 31, 1930. Other losses by death included Miss Ava L. Bennett, clerk stenographer, on November 11, 1929; Robert M. Campbell, bricklayer and plasterer, July 14, 1929; Ira W. Johnson, oiler, October 26, 1929; William L. Brawner, watchman, August 25, 1929; Walter J. Ferguson, watchman, October 8, 1929; and Mrs. Alberta Buchanan, charwoman, May 13, 1930.

Respectfully submitted.

ALEXANDER WETMORE,
*Assistant Secretary.*

# APPENDIX 2

## REPORT ON THE NATIONAL GALLERY OF ART

SIR: I have the honor to submit herewith my report on the operations of the National Gallery of Art for the fiscal year ending June 30, 1930.

### THE GALLERY COMMISSION

The ninth annual meeting of the gallery commission was held in the Regents' room of the Institution at 10.15 a. m., December 10, 1929, the members present being as follows: Mr. Gari Melchers, chairman; and Messrs. Herbert Adams, Charles L. Borie, jr., James E. Fraser, J. H. Gest, Frank J. Mather, jr., Charles Moore, James Parmelee, E. W. Redfield, E. C. Tarbell, and Dr. Charles G. Abbot, ex-officio.

Due to the absence of Dr. W. H. Holmes, secretary of the commission, Mr. James G. Taylor was requested to act as temporary secretary.

The minutes of the previous annual meeting were read and approved, followed by the reading and approval of the secretary's report on the activities of the gallery for the year.

A number of the matters mentioned in this report were discussed very fully and with reference to the Langhorne collection, the following resolution was adopted:

*Resolved*, That Mr. and Mrs. Marshall Langhorne be invited to loan to the National Gallery of Art their collection of paintings as a temporary exhibition, preferably at a time convenient to them as well as to the commission.

Doctor Abbot explained the steps taken in regard to the offer of Mr. John Gellatly and its acceptance, stating that through an act of Congress funds would be provided for the maintenance of the collection during the next four years. He added that special cards of admission to the collection in New York had been prepared and that he would be glad to supply the members of the commission with them. After discussion, the following resolution was adopted:

*Resolved*, That a committee consisting of Doctor Abbot and Mr. Melchers be appointed to prepare a formal acknowledgment of appreciation and thanks to Mr. Gellatly for his generous gift.

The acknowledgment duly prepared and forwarded is as follows:

JANUARY 6, 1930.

DEAR MR. GELLATLY: At the annual meeting of the National Gallery of Art Commission, held at the Smithsonian Institution, Washington, D. C., on the 10th day of December, 1929, the following resolutions were unanimously adopted:

*Resolved*, That the deep and appreciative thanks of this commission be, and they hereby are, extended to Mr. John Gellatly, of New York City, for his generous action in donating to the National Gallery of Art the fine and valuable art collection which, during a long term of years, he has assembled with so much pains and care, and with such rare discrimination and artistic taste.

*Resolved*, That this collection constitutes an important addition to the National Gallery of Art; that it will for all time to come be an outstanding feature of this Institution; and that it represents a great national asset in the development of the art of our country.

*Resolved*, That these resolutions be spread in full upon the minutes of this meeting, as a lasting tribute to the generosity of the donor, and that a copy thereof be transmitted to Mr. Gellatly with assurance of the warm regard and sincere appreciation of the members of the National Gallery of Art Commission, and with their cordial good wishes for his future health and happiness.

Sincerely yours.

(Signed) CHARLES G. ABBOT,
*Secretary, Smithsonian Institution.*
(Signed) GARI MELCHERS,
*Chairman, National Gallery of Art Commission.*

MR. JOHN GELLATLY,
*New York City.*

The Ranger exhibit was very fully discussed. It was the sense of the meeting that members of the commission should make their inspection of the exhibit entirely as individuals and that each member should give his personal expression of opinion in regard to the selections proper to be added to the National Gallery. It was also decided that these votes should be regarded as strictly confidential. The following resolution was adopted:

*Resolved*, That the commission extend to the Council of the National Academy of Design an invitation as a body to view the Ranger exhibit.

Mr. Moore brought up the matter, which had been referred to previously, of providing a fund for the encouragement and support of young artists until they had "arrived." He had not been successful in getting one of the large philanthropical organizations to arrange for this as yet, but he was glad to say that such provision had been incorporated in the will of a public-spirited citizen to become operative upon his death.

## EVENTS OF THE YEAR

Among the more noteworthy events of the year was the assemblage in Washington and exhibition in the gallery of the group of paintings purchased by the Council of the National Academy of Design in

accordance with provisions of the Henry Ward Ranger bequest. This bequest provides for the purchase from year to year of paintings by American artists which shall be assigned to art institutions throughout the country, the National Gallery being given the privilege of selecting from these purchases such examples as may be regarded as desirable additions to the national collections. There is thus established in perpetuity a procedure which should prove of prime importance in preserving a representative series of American paintings continuing from year to year and period to period, an historical measure not heretofore undertaken by any nation.

Purchases under the Ranger bequest began in 1920, and in 1930, 78 examples had been secured and distributed. The assemblage of these in Washington, December 10, 1929, was arranged to enable the gallery commission to inspect the works and make tentative selections for the national collection. Final steps on acceptance can not be taken, however, until within the 5-year period beginning 10 years after the artist's death in each case.

It has been suggested that acceptance of paintings by living painters be regarded as tentative acceptances only so that any work chosen may be returned to the recipient institution whence it came when a superior work by the same artist becomes available.

The addition of a single Ranger bequest work per year to the gallery would certainly not seem excessive, and at this rate in 100 years the gallery would be enriched by the ownership of 100 of the most masterly American works of the century.

Two distinct points of view may be held regarding acceptances of paintings by the gallery. First, that there should be included only recognized Old World masterpieces with possibly occasional and rare outstanding examples of American work of corresponding art value, and second that the National Gallery should first of all take this opportunity to build up an unbroken series of American works of the first order.

In the opinion of the director the authorities of the American National Gallery looking to the far future should not be content with accumulations of the art of the past, representing closed chapters of the history of art. As a great people we should have an assured art future, a future worthy of systematic record and representation.

A million Old World masterpieces installed in great American buildings will not make an American National Gallery, and in his view a commission or other official body concerned in the establishment of a national art collection should recognize the distinction

between the history of the world art of the past and the story of art in America to be revealed as the centuries and millenniums pass.

The essential concept of an American National Gallery is the assemblage of an adequate number of the best available products of the American brush (or chisel) from period to period and this is exactly what the Ranger bequest aims to do.

### SPECIAL EXHIBITIONS HELD IN THE GALLERY

The special exhibitions held in the gallery during the fiscal year formed no small part of its activities and are as follows:

#### THE HENRY WARD RANGER EXHIBITION

The exhibition of paintings purchased to date by the Council of the National Academy of Design from the Henry Ward Ranger fund, was opened on the evening of December 10, 1929, with a reception by the Secretary and Regents of the Institution, the director of the gallery, and the members of the National Gallery of Art Commission. The National Academy of Design was represented by Mr. Charles P. Curran, corresponding secretary; Mr. Albert P. Lucas, assistant corresponding secretary; Mr. Henry Prellwitz, treasurer; and Messrs. Charles S. Chapman, Ernest L. Ipsen, and Carl Rungius, of the council of the academy. The exhibit closed on January 31, 1930.

All of the paintings, 78 in number, are by outstanding contemporary American artists and, as stated above, under the terms of Mr. Ranger's will the National Gallery has the privilege of claiming any of them which it deems desirable for the national collections within the 5-year period beginning 10 years after the artist's death, and ending 15 years after his death. In the meantime the pictures are assigned by the Council of the National Academy of Design to institutions which maintain a free art gallery. These institutions lent the pictures for the present exhibition, in which for the first time the Ranger fund pictures have been assembled in one place. Payment of expenses of transportation and insurance was made possible through a grant of $1,000 voted by the Carnegie Corporation of New York. This grant was procured through the endeavors of Mr. Gari Melchers, chairman of the National Gallery of Art Commission.

Members of the National Gallery Commission submitted, confidentially, their votes as to the paintings exhibited which were suitable for permanent exhibition by the gallery. This vote is preserved for the information of those who in future will be charged with selecting pictures from the Ranger collections.

SCULPTURE BY EDGARDO SIMONE

An exhibition of 54 works of sculpture in plaster, bronze, and marble, by Signor Edgardo Simone, of Italy, was shown from February 8 to March 9, 1930, and included busts of S. E. Duce Benito Mussolini, the Rt. Hon. Sir Esme Howard, Justice Oliver Wendell Holmes, Gen. John J. Pershing, the Hon. George W. Wickersham, and others. Cards announcing the opening of the exhibit were issued by the gallery.

PORTRAITS BY EDWIN B. CHILD

An exhibition of 36 portraits in oil, by Edwin B. Child, of Dorset, Vt., of celebrities in the American educational and scientific worlds, was shown from February 15 to April 7, 1930. Cards announcing the exhibit were issued by the gallery.

PAINTINGS, SCULPTURES, ETC., BY CONTEMPORARY HUNGARIAN ARTISTS

An exhibition of paintings in oil, water-color, and pastel; sculpture in wood, bronze, and marble; etchings; and works of applied arts including metal work, etc., goldsmith's work, church plate, and textiles, by contemporary Hungarian artists, assembled by the Hungarian National Council of Fine Art, was shown under the patronage of Count László Széchenyi, minister from Hungary, and under the auspices of the American Federation of Arts and the American-Hungarian Foundation from April 23 to May 31, 1930. The exhibition was opened with a private view on April 23, invitations being issued by the regents and secretary of the Smithsonian Institution. An illustrated catalogue of 25 pages was furnished by the federation.

PAINTINGS BY AMERICAN NEGRO ARTISTS

An exhibition of paintings by American Negro artists, assembled under the auspices of the Harmon Foundation of New York and shown under the patronage of the committee on race relations of the Washington Federation of Churches, was held in the foyer of the Museum from May 30 to June 8, 1930. Cards announcing the opening of the exhibit were issued by the National Museum, the gallery being charged with the task of addressing and mailing the cards, installing the exhibit, and with the unpacking, packing, and shipping.

ART WORKS RECEIVED DURING THE YEAR

Accessions of art works by the Smithsonian Institution, subject to transfer to the National Gallery on approval of the advisory committee of the National Gallery of Art Commission, are as follows:

An oil painting, In the Studio, by A. Tamburini, Florence, received from Mme. Annita Gaburri, to be labeled "Presented in memory of Mrs. Ada Byron Gaburri by her granddaughter, Soldi Matier Wilcox." (Deposit.)

A beautiful example of enamel work in the form of a watch by Moulinié & Legandory, Geneva, Switzerland; bequeathed to the Institution by Miss Charlotte Arnold H. Bryson, late of Wilmington, Delaware. (Deposit.)

Original plaster models of busts of prominent American personages made by Moses Wainer Dykaar during the last decade as follows; presented by the sculptor with the understanding that they be available to him when needed. It is also understood that the Institution shall not make copies of these without Mr. Dykaar's permission:

Dr. Charles D. Walcott.
Hon. Robert L. Owen.
Hon. Thomas R. Marshall.
Hon. Champ Clark.
Samuel Gompers.
Hon. Nicholas Longworth.
Mrs. Nicholas Longworth.
Gen. George Owen Squier.
Edwin Markham.
Alexander Graham Bell.
Hudson Maxim.
Justice Wendell P. Stafford.
Adm. George Collier Remey.
William Henry Holmes.
Hon. Charles Curtis.
Calvin Coolidge.
Mrs. Calvin Coolidge.
Hon. Carter Glass.

LOANS ACCEPTED BY THE GALLERY

A painting by an old master, attributed to Bartolommeo Schidone (1560–1616) representing the Madonna and Child; lent by Mme. Bronislava De Brissac Hulitar, of New York City, through Hon. Carroll L. Beedy, M. C.

A Madonna, by Giovanni Battista Salvi (1605), the property of Mrs. Charles J. Fox of Tientsin, China; lent through Miss Genevieve B. Wimsatt, of Washington, D. C.

The Italian masterpiece, the Immaculate Conception with the Mirror, by Murillo; withdrawn by the owner on June 24, 1929; was again lent by Mr. DeWitt V. Hutchings of Riverside, Calif., March 22, 1930.

Minerva, an original oil painting of the sixteenth century—relic of the Spanish Conquest of Central American as described by the owner; lent by Miss May Warner, Washington, D. C.

Four portraits: Admiral Holdup Stevens, 2d, by Robert Hinckley, Mrs. Thomas Holdup Stevens, 2d, by an artist unknown, Mrs. John Bliss (sister of Mrs. Stevens) by an artist unknown, and Hon. Eben Sage of Middletown, Conn., by Chester Harding; lent by Mrs. Frederick C. Hicks, Washington, D. C.

Bust in bronze by Joseph Anthony Atchison, of Dr. John Wesley Hill, chancellor of Lincoln Memorial University, Cumberland Gap, Tenn.; lent by Joseph Anthony Atchison, Washington, D. C.

Five paintings: Head of Christ attributed to Giorgione, Holy Family and St. John by M. Albertinelli, Baptism of Christ by G. B. Tiepolo, the Doctor's Visit by Jan Steen, and Italian Landscape by Richard Wilson; lent by Mrs. Marshall Langhorne, Washington, D. C., June 16, 1930.

Portrait bust in marble by Moses Wainer Dykaar of Hon. Nicholas Longworth, Speaker of the House of Representatives; lent by the sculptor.

A water-color painting of dogwood blossoms by Elizabeth Muhlhofer, of Washington, D. C.; lent by the artist.

### DISTRIBUTIONS

Three paintings: Madonna and Child by Alonzo Cano, Madonna by Carlo Dulci, and Saint with Book by Giuseppe Ribera (Spagnoletto); withdrawn by the owners, Mr. and Mrs. Maxim Karolik, of Washington, D. C.

The Old Mill, a painting attributed to Hobbema, lent by Mrs. Mary F. C. Goldsborough; withdrawn by the executor of Mrs. Goldsborough's estate, Edmund K. Goldsborough, Washington, D. C.

Bust in bronze of Hon. Wade H. Cooper by Joseph Anthony Atchison, lent by the sculptor; withdrawn by Mr. Atchison.

The portrait by Gambardella of Mrs. Charles Eames, lent yearly by Mrs. Alistair Gordon Cumming was withdrawn for the winter by Mrs. Cumming.

Four paintings: Baptism of Christ by G. B. Tiepolo, Christ in the Temple by G. B. Tiepolo, Head of Christ attributed to Giorgioni, and Portrait of Henry, Prince of Wales (or Prince Charlie) by C. Janssens van Ceulen; withdrawn by Mrs. Marshall Langhorne in the autumn of 1929.

### LOANS RETURNED TO THE GALLERY

The painting by Alexander Wyant entitled The Flume, Opalescent River, Adirondacks, one of two from the William T. Evans collection lent to the White House on request of Mrs. Herbert Hoover in May, 1929, has been returned to its former place in the gallery.

### THE HENRY WARD RANGER FUND PURCHASES

The paintings purchased during the year by the Council of the National Academy of Design from the fund provided by the Henry Ward Ranger bequest, which are under certain conditions prospec-

tive additions to the National Gallery collections, are as follows, including the names of the Institutions to which they have been assigned:

| Title | Artist | Date of purchase | Assignment |
|---|---|---|---|
| 77. Near Monterey | Arthur Hill Gilbert, A. N. A. (elect). | December, 1929 | Springville High School Art Association, Springville, Utah. |
| 78. Margery and Little Edmund. | Edmund C. Tarbell, N. A. | do | The Grand Rapids Public Library, Grand Rapids, Mich. |
| 79. Gold Mining, Cripple Creek. | Ernest Lawson, N. A. | April, 1930 | Charleston Public Library Board (Charleston, West Virginia, Art Association). |
| 80. Big Starbuck | Roy Mason, A. N. A. (elect). | do | Reading Public Museum and Art Gallery, Reading, Pa. |

The paintings purchased during former years and unassigned at the close of the last fiscal year (1929) have been subsequently assigned as follows:

68. Mlle. Maria Safanoff, by Irving R. Wiles, N. A.; to Mount Holyoke College, South Hadley, Mass.

71. The Harvest Moon. by Charles Melville Dewey, N. A.; to the Fine Arts Society of San Diego, San Diego, Calif.

76. Fishing Fleet, by Malcolm Humphreys; to Davenport Municipal Art Gallery, Davenport, Iowa.

### COPYING PAINTINGS

While the gallery has no facilities for the accommodation for artists desiring to copy works of art in its collections, permission is given in special cases. During the present fiscal year two artists, both of Washington, D. C., were permitted to copy portraits in the Harriet Lane Johnston collection: Mrs. Charles H. L. Johnston (Birdie Abbott Johnston) copied the portrait of Lady Hammond by Sir Joshua Reynolds, and Miss Angelica Frances Small copied the portrait of Miss Kirkpatrick by George Romney.

### LIBRARY

The gallery library continued to increase by gift, purchase, and subscription in volumes, pamphlets, periodicals, etc., Mr. J. Townsend Russell, jr., being the principal benefactor of the year.

### PUBLICATIONS

HOLMES, W. H. Report on the National Gallery of Art for the year ending June 30, 1929. Appendix 2, report of the secretary of the Smithsonian Institution for the year ending June 30, 1929, pp. 1–9.

LODGE, J. E. Report on the Freer Gallery of Art for the year ending June 30, 1929. Appendix 3, report of the secretary of the Smithsonian Institution for the year ending June 30, 1929, pp. 10–16.

Catalogue of an exhibition of paintings by contemporary American artists purchased by the Council of the National Academy of Design from the Henry Ward Ranger fund in accordance with the provision of the Ranger bequest dated January 21, 1914. On view in the National Gallery, Natural History Building, United States National Museum, December 10, 1929, to January 31, 1930. United States Government Printing Office, Washington: 1929.

Exhibit of Sculptures by Edgardo Simone, National Gallery of Art, United States National Museum, February 8 to 28, 1930, inclusive. Leaflet of 3 pp. privately printed.

Catalogue of a group of portraits in oil by Edwin B. Child on view in the National Gallery of Art in the United States National Museum, February 15 to March 30, 1930. Leaflet of 4 pp., privately printed.

Catalogue of an Exhibition of Paintings, Sculpture, and Works of Applied Arts by Contemporary Hungarian Artists shown under the auspices of the American Federation of Arts and the American-Hungarian Foundation. Exhibited at The National Gallery of Art, Smithsonian Institution, April 23–May 31, 1930. Washington, D. C. (Pp. 1–25; 16 plates, privately printed.)

Catalogue of an Exhibition of Paintings by American Negro Artists at the United States National Museum, Smithsonian Institution, Washington, D. C. May 30–June 8, 1930. Price 25 cents. (Pp. 1–15; 9 illustrations on 6 plates. Washington, privately printed.)

Respectfully submitted.

W. H. HOLMES,
*Director.*

DR. C. G. ABBOT,
*Secretary, Smithsonian Institution.*

28095—31——5

# APPENDIX 3

## REPORT ON THE FREER GALLERY OF ART

SIR: I have the honor to submit the tenth annual report on the Freer Gallery of Art for the year ending June 30, 1930:

### THE COLLECTIONS

Additions to the collections by purchase are as follows:

#### BOOKBINDING

30.46. Egyptian, fourteenth century. Dark brown leather on pasteboard, lined with chestnut brown leather. Decoration in blind and gold tooling.

30.47. Egyptian, fourteenth century. Dark brown leather on pasteboard, lined with lighter brown leather. Decoration in blind and gold tooling.

#### BRONZE

30.26. Chinese, fifth century B. C. A ceremonial wine jar of the type *yü*, with a bail handle.

30.37. Chinese, period of the Sui dynasty (A. D. 589–618). A mirror, with the back decorated with six panels containing galloping animals in relief. The addition of red and green color to the central medallion is unusual.

30.38. Chinese, eighth to ninth century. T'ang period. A mirror with a scalloped edge. The back is decorated with floral designs in relief.

30.45. Chinese, seventh to tenth century. T'ang period. A mirror with a festooned rim. The back is covered by a sheet of gold, decorated with an embossed scroll design containing flowers and birds.

30.54. Chinese, eleventh century, B. C. Early Chou period. A ceremonial vessel, of the type *fang i*. White bronze patinated with azurite, malachite, and cuprite. Inscriptions inside of the cover and the body of the vessel.

#### JADE

Chinese, Han period (206 B. C.–A. D. 220). A group of objects from a single burial, as follows:

30.27. A necklace made of four strands of gold wire, braided, to which are attached four carved pendants and six cylindrical beads of white jade.

30.28–30.29. Two combs of white jade, with a formal carved ornament at the top.

30.30. A hair ornament (?) of carved white jade, somewhat altered by burial.

30.31. A peach-shaped cup on a low foot, of greenish-white jade, with cream-colored areas of alteration. A delicate engraved pattern is on the outside of the cup.

30.43. A figure of a dancer, a detached ornament, carved in white jade.

MANUSCRIPTS

30.1. Persian, thirteenth to fourteenth century. A ms. copy of the *Shāh Nāmah*, with leaves detached from the binding, containing 42 miniatures, 29.25–47, 30.2–20. (See under *Painting.*)

30.23–30.24 Egyptian, eighth to ninth century. Two parchment leaves from a Korān, written in *Kūfic* script on both sides in black and red with additions of gold.

30.55. Egyptian, fourteenth century. Mamlūk period. A double title page from a Korān, richly illuminated in colors and gold. Vellum.

30.56–30.59. Egyptian, fourteenth century. Mamlūk period. Four leaves from a Korān with illuminated chapter headings and other ornaments. Vellum.

30.60–30.70. Egyptian, eighth to ninth century. Eleven leaves from a Korān written in *kūfic* script in dark brown ink with dots of red and gold. One illuminated title. Vellum.

PAINTING

30.2–30.20. Persian, thirteenth to fourteenth century. Mongol period. Nineteen miniatures in colors and gold, illustrating episodes in the *Shāh Nāmah* (see 30.1 above).

30.21. Persian, thirteenth to fourteenth century. Mongol period. A miniature in colors and gold on paper; an illustration in a Persian translation of the Universal History by Muhammad Ibn Djarīr al Tabarī.

30.22. Indian, early seventeenth century. Mughal, School of Jahāngir. Portrait of a young prince. In colors and gold on paper.

30.25. Indian, seventeenth century. Rajput, Basohli School. Śri-Krishna rises to welcome Sudāmā. In full color and gold on paper.

30.36. Chinese, dated in correspondence with A. D. 968. Sung dynasty. A painting on silk from "The caves of a thousand Buddhas" at Tunhuang. The deity Avalokiteśvara with two attendant divinities. In the register below, the family of the donor is portrayed, and an inscription records the offering.

30.48–30.49. Persian, Fifteenth century. Timurid period. Two miniature paintings in colors and gold on paper, illustrating episodes in the *Shāh Nāmah.* The first shows a group of warriors; the second, a prince receiving two personages.

30.71–30.77. Egyptian, early fourteenth century. Mesopotamian school. Seven miniatures in full color and gold, originally illustrations in a ms. book on *Automatics.*

30.78. Persian, fourteenth century. Mongol period. A miniature painting in colors and gold on paper. An illustration of an episode in the *Shāh Nāmah*, showing a king reclining within an arched doorway, his horse tethered outside.

PORCELAIN

29.83. Chinese, early eighteenth century. Yung Chêng period. A bowl made at the Ku Yüeh Hsüan studio for imperial use. The exterior is decorated with four landscape vignettes executed in red enamel over glaze, with inscriptions in black. The space between the vignettes is filled with a *mille-fleur* design in colored enamels, over glaze. Reign mark, in blue enamel.

30.35. Chinese, early eighteenth century. Yung Chêng period. A small bowl of the Ku Yüeh Hsüan type, decorated with a design of black birds and autumnal branches in over-glaze enamels. Reign mark, in blue enamel.

POTTERY

29.82. Chinese, twelfth to thirteenth century. Sung dynasty. A bowl of Ting ware, with extremely thin walls, decorated with a phoenix and cloud design, stamped in the paste, under a transparent colorless glaze.

30.32. Chinese, T'ang dynasty. (A. D. 618–907.) A large ovoid jar, decorated with medallions in relief. It was originally glazed in green; now largely altered to a silvery iridescence.

30.33–30.34. Chinese, T'ang dynasty. A long-necked bottle, with trefoil mouth, ornamented with medallions in relief, and accompanied by a high stand, with cut-out openings in its sides. Both bottle and stand were glazed in green, which has altered to a silvery iridescence.

SCULPTURE, BRONZE

29.84. South Indian, late eleventh or early twelfth century. Cola period. A processional image of Pārvatī or of a deified queen. Black patina.

SILVER

30.40. Chinese, T'ang dynasty. A ladle, with a long curved handle and lobed bowl. A delicate floral ornament is engraved on the outside of the bowl and on the handle.

30.42. Chinese, T'ang dynasty. A small covered cup, the outside ornamented with a delicate engraved floral design, against a stippled ground.

30.50. Chinese, T'ang dynasty. A box in the form of a clamshell, hinged. The outside is engraved with a bird and flower scroll design, against a stippled ground. The larger areas of the design show traces of gilt.

30.51. Chinese, T'ang dynasty. A cup with a curved, foliated handle. The outside is covered with a delicate engraved design of birds and animals in a grape-vine scroll. The larger areas are gilded. The ground is filled with stippling.

30.52–30.53. Chinese, T'ang dynasty. Two small round boxes with fitted covers. The outsides of both are decorated with delicate engraved designs of bird and flower scrolls, of different patterns, on a stippled ground. The larger areas are gilded.

SILVER-GILT

30.39. Chinese, eighth-ninth century. T'ang dynasty. A melon-shaped box with eight lobes, covered with a grape-vine design, carved in slight relief and gilded. The finial is a toad-like figure, in high relief.

30.41. Chinese, ninth century. T'ang dynasty. An oblong lobed cup on a high lotus-leaf base. Both inner and outer surfaces are covered with delicate engraved designs, and in the center of the bowl is a rosette, in repoussé relief.

30.44. Chinese, ninth century. T'ang dynasty. A circlet for a head of a Buddhist divinity, decorated with figures of *apsarases* with musical instruments, among foliated scrolls, in repoussé relief. The ground is filled with fine stippling.

Curatorial work within the collection has as usual included the documentary study of inscriptions on the new purchases from the Far East, as well as those upon objects already in the collection. Many objects and reproductions of objects have been submitted by other institutions and by private owners for expert opinion or for translation of inscriptions in Chinese, Japanese, or Tibetan. The total number of such reports made by the curator embraces 834 objects and 185 photographs of objects.

During the winter a large group of paintings in the Near Eastern section, which was purchased *en bloc* in 1907 from its then owner, Col. H. B. Hanna, and which comprised a miscellany of Mughal, Rajput, and Persian paintings, has undergone complete revision and reclassification. In this work the curator has had the expert assistance of Dr. A. K. Coomaraswamy, of the Museum of Fine Arts, Boston. The entire collection of Near Eastern painting and manuscript leaves is now in process of being remounted and stored in boxes of an improved type made in the Freer Gallery shop for this purpose. The collection of Chinese bronzes, also, has been given a new and improved type of storage so arranged as to be most easily accessible to the student.

The care and preservation of objects in the collection has this year included work that can be itemized as follows:

(1) Remounted:
- 2 Chinese panel paintings.
- 1 Chinese scroll painting.
- 3 Japanese panel paintings.
- 2 Japanese screen paintings.

(2) Restored and rebacked.
- 2 Chinese velvet wall hangings.

(3) Repaired:
- 11 pages of Egyptian calligraphy on parchment.
- 7 Persian paintings.

Changes in exhibition have involved a total of 243 objects as follows:

- 49 Whistler etchings.
- 45 Whistler lithographs and lithotints.
- 46 Whistler water-color paintings.
- 13 Whistler pastel drawings.
- 2 Chinese bronze vesssels.
- 2 Chinese bronze mirrors.
- 1 Chinese bronze and gold mirror.
- 1 Chinese bronze sword.
- 6 Chinese jades.
- 3 pieces of Chinese silver.
- 2 pieces of Chinese silver-gilt.

3 Chinese paintings.
5 Chinese porcelains.
5 pieces of Chinese pottery.
2 velvet wall hangings.
6 Egyptian bookbindings.
4 Indian paintings.
6 Japanese screens.
8 Japanese panels.
19 Persian paintings.
1 South Indian bronze.
1 piece of Syrian enameled glass.
13 pages of calligraphy.

On March 25, 1930, a special exhibition of "New Accessions" was opened to the public, in Galleries I and II.

### THE LIBRARY

During the year, there have been added to the main library 93 volumes, 37 unbound periodicals, and 229 pamphlets. Twenty-nine volumes were sent to the bindery. A list of the new accessions to the library accompanies this report as Appendix A (not printed).

The library is in process of being catalogued under the direction of the librarian of the Smithsonian Institution, Mr. W. L. Corbin. This work was begun in November, 1929, and is not yet completed.

### REPRODUCTIONS AND PAMPHLETS

Four hundred and five new negatives of objects have been made. Of these, 182 were made for registration photographs and 223 for special orders. The total number of reproductions available either as carbon photographs or as negatives from which prints can be made upon request is now 3,094.

Eighty-two lantern slides have also been added to the collection, making a total of 911 available for study and for sale.

The total number of sales of reproductions, at cost price, is as follows: Photographs, 1,600; post cards, 16,683; lantern slides, 79; negatives, 2. Eighty-three lantern slides have been loaned for lecture purposes.

Of booklets issued by the gallery, the following number were sold at cost price:

| | |
|---|---|
| F. G. A. pamphlets | 150 |
| Synopsis of History pamphlets | 116 |
| List of American paintings | 53 |
| Annotated Outlines of Study | 22 |
| Gallery books | 259 |
| Floor plans | 11 |

### BUILDING

The work of repairing the building has included this year the repainting of the corridors on the lower floor, and of Galleries III and IV. The shop has been constantly occupied with the building of equipment of various sorts, including new cases for bronze storage, other exhibition cases and easels, and, interesting for its novelty, a motor-driven machine for the unrolling of Chinese scrolls before a moving-picture camera. The report of the superintendent, which gives a detailed account of shop work, accompanies this report as Appendix C (not printed).

### ATTENDANCE

The gallery has been open every day, from 9 until 4.30 o'clock, with the exception of Mondays, Christmas Day, and New Year's Day.

The total attendance for the year was 120,651; the total attendance for week days, 80,624; the total Sunday attendance, 40,027. The average Sunday attendance is more than twice as great as that of week days; 769 being the average Sunday attendance, and 310 the average for week days. The two peaks of the year were reached in August and April, with totals of 17,800 and 17,541, respectively; the lowest attendance was that of January, with a total of 5,561.

The total number of visitors to the offices was 1,349. Of these, 156 came for general information; 172 to call upon upon members of the staff; 308 to see objects in storage; 116 to submit objects for examination; 16 to study the building and installation methods; 128 to study in the library; 95 to see the reproductions of the Washington Manuscripts; 15 to make photographs and sketches, and 3 to make tracings; while 212 came to purchase photographs.

Sixteen groups, ranging from 1 to 30 persons, were given docent service in the exhibition galleries, and 10 classes in groups ranging from 3 to 8 persons were given instruction in the study room.

Two lectures by eminent authorities in their respective fields were given during the winter in the auditorium at the Freer Gallery. These were as follows:

January 6, 1930: Sir Aurel Stein on "The Caves of the Thousand Buddhas"; illustrated.

February 20, 1930: Dr. A. K. Coomaraswamy on "Indian Sculpture: Intention and Development"; illustrated.

On May 7, at 5 o'clock, in compliment to the Library of Congress, the auditorium was opened to the society of "The Friends of Music in the Library of Congress," for a concert of music written for harpischord, piano, viola d'amore, and viola.

FIELD WORK

In spite of greatly disturbed conditions now and long since prevailing in China, Mr. Bishop was able, last spring, to make investigations of considerable interest at the site of the Liang dynasty (A. D. 502–556) tombs, not far from Nanking. The detailed report on these excavations has not yet been received; but, meanwhile, copies of Mr. Bishop's letters from the field are submitted herewith as Appendix B (not printed).

In June, after a profitable winter at the Imperial University, Kyōto, Mr. Wenley joined Mr. Bishop in China. He has been recalled for work at the gallery where he is due to arrive next December.

Mr. Acker has been making excellent progress in his Chinese studies at the University of Leiden, and has also found opportunity to see some of the important Chinese collections in Paris, Berlin, and Stockholm. He will pass one more school year under Professor Duyvendak at Leiden.

PERSONNEL

Miss Christabel E. Hill, stenographer to the field staff, resigned from her position August 23, 1929.

Mr. Carl W. Bishop, associate curator, left for field work in China on November 16. He was married to Miss Daisy Furscott in Berkeley, Calif., on November 30.

Miss Eleanor Thompson took up her position as office assistant on November 15, 1929.

Dr. Ananda K. Coomaraswamy spent July 12, February 19 and 20, in reclassifying Persian and Indian paintings and drawings.

Mr. Y. Kinoshita worked at the gallery from February 1 to June 26, on the preservation of oriental paintings.

Mrs. R. W. Edwards, who has been associated with the Freer Gallery since February, 1924, resigned from her position on May 22, 1930, because of removal from the city.

Mrs. R. W. Helsley, who was at the Freer Gallery between November, 1920, and March, 1922, returned to it on May 5, 1930, by transference from the administration office, National Museum.

Dr. Chi Li, ethnologist, who has been associated with the field staff in China for several years, resigned his position on June 30, 1930, to take up other scientific work in Peiping.

Respectfully submitted.

J. E. Lodge,
*Curator, Freer Gallery of Art.*

Dr. C. G. Abbot,
*Secretary, Smithsonian Institution.*

# APPENDIX 4

## REPORT ON THE BUREAU OF AMERICAN ETHNOLOGY

SIR: I have the honor to submit the following report on the field researches, office work, and other operations of the Bureau of American Ethnology during the fiscal year ended June 30, 1930, conducted in accordance with the act of Congress approved February 20, 1929. The act referred to contains the following item:

> American ethnology: For continuing ethnological researches among the American Indians and the natives of Hawaii, the excavation and preservation of archeologic remains under the direction of the Smithsonian Institution, including necessary employees, the preparation of manuscripts, drawings, and illustrations, the purchase of books and periodicals, and traveling expenses, $68,800.

Mr. M. W. Stirling, chief, in the month of August, 1929, visited Gallup, N. Mex., from whence he went to the Long H Ranch, Ariz., in order to view the archeological excavations being conducted there by Dr. F. H. H. Roberts, jr., of the bureau staff. From the Long H Ranch he proceeded to Pecos, N. Mex., for the purpose of attending the Conference of Southwest Archeologists, which was held at the site of the excavations being conducted by Dr. A. V. Kidder.

From Pecos Mr. Stirling went to Hanover, N. H., to deliver an address before the annual meeting of the Social Science Research Council.

On February 1 Mr. Stirling went to Key West, Fla., where, through the courtesy of Mr. Lee Parish, he was enabled to conduct an archeological reconnaissance of the Ten Thousand Islands in Mr. Parish's yacht, the *Esperanza*. Upon the completion of this reconnaissance a visit was made to Lacooche, Fla., where a small mound was excavated. Mr. Stirling next proceeded to Tampa Bay, where a large sand mound near Safety Harbor was excavated.

Work was continued on the preparation of manuscript descriptive of the field work, and a number of short articles were prepared and published in various periodicals. Frequent lectures on anthropological topics were given during the year before various scientific and educational bodies.

Dr. John R. Swanton, ethnologist, conducted field work during July and August, 1929, in Mississippi and Oklahoma. He collected further ethnological material from the Mississippi Choctaw, and

corrected notes that were obtained the year before. In Oklahoma Doctor Swanton visited most of the existing Square Grounds of the Creeks, witnessed parts of several ceremonies, and obtained descriptions of their ceremonial arrangement. The Choctaw material has been incorporated in his manuscript, "Source Book for the Social and Ceremonial Customs of the Choctaw," which is ready for publication. The data Doctor Swanton collected on Creek Square Grounds will form a short paper and is ready for publication.

Doctor Swanton corrected throughout the words of his Timucua dictionary, completing work begun last year; and in addition he began the work of translating them, with the help of the original Timucua-Spanish religious works in which the material is preserved. Further work was done on the map of Indian tribes, the scope of which has been extended so as to cover Mexico, Central America, and the West Indies; the accompanying text has also been amplified. On June 20 Doctor Swanton left Washington to resume field work in the State of Louisiana.

On July 1, 1929, Dr. Truman Michelson, ethnologist, went to Shawnee, Okla., to continue his study of the Algonquin Tribes of that State, where he obtained a fairly representative collection of Kickapoo mythology. From these studies Doctor Michelson found that his statement made 14 years ago that Kickapoo mythology, on the whole, is closest to Fox mythology, still holds valid. It should be mentioned that Kickapoo shares with certain northern Indian tribes a number of tales which are either absent from the Fox or their knowledge is confined to but few of them. Despite some secondary changes, Kickapoo is an archaic Algonquian language. It may be added that their religious ideas and practices hold their own with great vigor. Obviously, the type of social organization is quite similar to those of the Sauk and Fox. Work among the Sauk and Shawnee was chiefly linguistic. The new data clearly show that Shawnee is further removed from Sauk, Fox, and Kickapoo than supposed; yet it is abundantly clear that it is closer to them than to any other Algonquian languages. Only a short time was given to Cheyenne, practically nothing but linguistics being considered. The opinion given by Doctor Michelson in the twenty-eighth annual report of the bureau that Cheyenne must be considered aberrant Algonquian is fully sustained. Some social customs were noted, among them male descent. Work among the Arapaho was mainly linguistic.

A large part of the time in the office was spent in preparing for publication a large memoir on the Fox Wâpanõwiweni. This is now in an advanced stage of preparation. He also corrected the proofs of Bulletin 95 of the bureau which was issued during the year.

On June 3, 1930, Doctor Michelson left Washington to renew his work among the Algonquin Tribes of Oklahoma. He spent at first a

short time on the Cheyenne. It is now possible to formulate some of the phonetic shifts that have transformed Cheyenne from normal Algonquian. It is also clear that some of the commonest words in normal Algonquian are lacking. He then took up work again among the Kickapoo and obtained an even larger body of myths and tales. Some new facts on their social organization were likewise obtained.

Mr. John P. Harrington, ethnologist, worked during the year securing the language and much of the ethnology of the San Juan tribe of California through an aged and ill informant, Mrs. Ascensión Solórsano, at Monterey, Calif. Having learned the language which has scarcely been spoken since 1850, through the circumstance that both her mother and father, who were fullblooded Indians, talked it together all their lives, the mother dying at 84 years of age and the father at 82, she retained a knowledge of an extinct language and a dead culture, and lived long enough to enable Mr. Harrington to record practically all that she knew, thus filling in a great blank in California ethnology. So sick that she was scarcely able to sit up even at the beginning of the work, Mr. Harrington continued this work at her bedside until well into January, 1930, and no Indian ever showed greater fortitude than this poor soul who served the bureau up to almost her last day. The material recorded consisted of every branch of linguistic and ethnological information and contains many new and important features.

Mrs. Solórsano during all the latter part of her life was recognized as a *doctora*. Her little home at Gilroy, Calif., was a free hospital for down-and-outs of every nationality and creed, and here the sick and ailing were treated with Indian and Spanish herb medicines and were seen through to the last with motherly care and no thought of recompense. Mr. Harrington obtained full accounts of how she treated all the various diseases, and of the herbs and other methods employed. Specimens of the herbs were obtained and identified by the division of plants of the National Museum.

Songs were obtained on the phonograph, and accounts of ceremonies, and description of all the foods of the Indians and how they were cooked were obtained. Accounts of the witcheries of the medicine men take us back to earliest times, and are mingled with the early history of the tribe at the San Juan Mission. Many stories and anecdotes about early Indians were recorded and throw much light on the thought and the language of the times. Names of plants and animals and places were studied and identified, Dr. C. Hart Merriam generously helping in this and other sections of the work. In spite of her age and infirmities Dona Ascensión's mind remained remarkably clear and her memory was exceptional. No greater piece of good fortune has ever attended ethnological research of a tribe that was culturally of the greatest importance,

forming an all but lost link between the cultures of northern and southern California.

After the death of Dona Ascensión at the end of January, 1930, Mr. Harrington spent some weeks in checking up on the information in every way possible, copying from the archives at San Juan Mission, working at the Bancroft Library at Berkeley, Calif., and interviewing many individuals, and returned to Washington in April, since which time he has been engaged in preparing a report on the work for publication.

Dr. F. H. H. Roberts, jr., archeologist, devoted the fiscal year to a number of activities. July, August, and the first part of September, 1929, were spent conducting excavations at the Long H Ranch, between St. John's and Houck, in eastern Arizona. The work was begun in May and continued through June of the preceding fiscal year so that the investigations extending from July to the middle of September were a continuation of work already under way. At the completion of the summer's work the remains of three different types of houses had been uncovered. These included 18 pit houses, the vestiges of three jacal, pole and mud structures, and a pueblo ruin with 49 rooms, and 4 kivas or circular ceremonial rooms.

The pit houses were found to correspond in many respects with those dug up by Doctor Roberts in the Chaco Canyon, in northwestern New Mexico, during the summer of 1927 and described in Bulletin 92 of the Bureau of American Ethnology. The jacal houses were found to have been quite comparable to a similar type found in southern Colorado during the field season of 1928. The latter were extensively described in Bulletin 96 of the bureau. The pueblo revealed an unusually clear cut story of the growth and changes in a communal dwelling. The building had not been erected according to a preconceived plan but had grown by degrees through the addition of new units. It was quite evident that such additions had taken place at four different periods in the occupation of the building.

Doctor Roberts returned to Washington in October. The autumn months were devoted to reading and correcting galley and page proofs for the report on the investigations of the 1928 field season. This paper is called "Early Pueblo Ruins in the Piedra District, Southwestern Colorado," and is Bulletin 96 of the bureau.

The winter months were devoted to working over the specimens obtained from the summer's excavations and preparing a report on the investigations. This included the drawing of 31 text figures, consisting of 70 drawings, 1 map showing the region in general and the location of the sites, and the writing of a 600-page manu-

script. The latter is called "The Ruins at Kiatuthlanna," the Zuñi Indian name for the locality.

Doctor Roberts assisted Mr. Neil M. Judd of the United States National Museum in cataloguing the collections made along the Piedra River in southwestern Colorado in the summer of 1928. Illustrated lectures on the archeology of the Southwest were delivered before a number of Washington organizations, and information on the archeology of the New World was supplied in response to many letters of inquiry.

On May 12, 1930, Doctor Roberts left Washington for Denver, Colo., where one week was spent in studying new accessions in the Colorado State Museum and the City Museum of Denver.

Leaving Denver, Doctor Roberts proceeded to Gallup, N. Mex., and from there to the Zuñi Indian Reservation. One week was devoted to an archeological reconnaissance of the Zuñi area. As a result of this a small pueblo ruin was chosen as the scene for intensive investigations, and under a permit from the Department of the Interior excavations were started. By July 1 a burial mound containing 40 interments had been investigated and 16 rooms and 2 kivas or ceremonial chambers in the pueblo had been cleared of their accumulated débris. In addition to much valuable information, 150 specimens, including pottery and other art facts, had been secured.

Mr. J. N. B. Hewitt, ethnologist, was engaged in routine office work from July 1, 1929, to May 7, 1930, and from the latter date until the close of the fiscal year he was engaged in field service in Canada and very briefly in New York State.

Mr. Hewitt devoted much careful research among various documents to ascertain, if possible, the symbolic significance of white and purple wampum beads, respectively, and also when these are mixed in definite proportions and arrangement on strings or belts; but much reading of documents which might bear on the question was comparatively barren of any satisfactory results. He was led to this study because, in modern time at least, strings of wampum function and have functioned quite prominently in the public transactions of the Council of the League of the Iroquois. Wampum strings are an essential accompaniment in the use of the ritual of the Requickening Address of the Council of Condolence and Installation of the League.

Mr. Hewitt also transliterated an Ottawa mythic text from the common missionary alphabet into that of the Powell phonetic system designed for the use of collaborators of the bureau.

He also typed in native Mohawk text the chanted ritual, the Eulogy of the Founders of the League, as intoned by the Father

Tribal Sisterhood, incorporating therein such revisional additions, textual and grammatic, as had been found necessary by extensive field studies. Mr. Hewitt also typed in native Onondaga text this ritual in the form in which it is intoned by the Mother Tribal Sisterhood; these two versions of the eulogy differ chiefly in the introductory paragraphs and also in the terms or forms of address. Mr. Hewitt continued to represent the Bureau of American Ethnology, Smithsonian Institution, on the United States Geographic Board, and as a member also of its executive committee.

On the afternoon of May 7, 1930, Mr. Hewitt left Washington on field duty, returning to the bureau July 1. During this trip he visited the Grand River Reservation of the Six Nations of Indians near Brantford, Canada, the Tuscarora Reservation near Niagara Falls, N. Y., and the Onondaga Reservation near Syracuse, N. Y. Largely through his own knowledge of the several Iroquois languages, he was able to recover the hitherto lost meanings of several passages in the texts relating to the league. These recoveries now make the entire structure of the League of the Iroquois clear and consistent.

During the fiscal year Dr. Francis LaFlesche, ethnologist, read the proof of his paper "The Osage Tribe: Rite of the Wa-xo-be," which will be published in the forty-fifth annual report of the bureau. At the time of Doctor LaFlesche's retirement, December 26, 1929, he had nearly completed an Osage dictionary upon which he had been working for several years.

### SPECIAL RESEARCHES

The music of 10 tribes of Indians has been studied during the past year by Miss Frances Densmore, a collaborator of the bureau, in continuance of her research on this subject. These tribes are the Acoma, Menominee, Winnebago, Yuma, Cocopa, Mohave, Yaqui, Makah, Clayoquot, and Quileute. The first tribe given consideration was the Acoma, the work consisting in a completion of the study of records made in Washington by Philip Sanche. These records were made for the chief of the Bureau of American Ethnology. Thirteen were transcribed as representative of the series. An outstanding peculiarity of these songs is a gradual raising or lowering of the pitch during a performance. In some instances the pitch was changed a semitone, in others a tone and a half, and one example contained a rise of a whole tone during one minute of singing. This was regarded as a mannerism and the song was transcribed on the pitch maintained for the longest time.

The work on Yuman and Yaqui music consisted in the retyping of almost all the text on these tribes, made necessary by the combining

of individual manuscripts into a book. The analysis of each song was scrutinized and several songs previously classed as "irregular in tonality" were otherwise classified. The preparation for publication of a book on Menominee music has been practically completed. The manuscript contains 460 pages, with transcriptions of 140 songs, and a large number of illustrations. The material collected at Neah Bay, Wash., and submitted in the form of 13 manuscripts during previous years, has been unified under chapter headings and retyped for publication. Interesting features of these songs are the prominence of the tetrachord and the large number of songs with a compass of three or four tones.

In July and August, 1929, a field trip was made to the Menominee and Winnebago in Wisconsin, the former tribe receiving the more consideration. This was the third visit to the Menominee and work was done at Keshena, Neopit, and Zoar. In June, 1930, another trip was made to the Winnebago in Wisconsin, this being the fourth visit to that tribe. Songs were recorded in the vicinity of Tomah and also near Wisconsin Rapids. One of the singers at the former locality was Paul Decora, whose home is in Nebraska. Fourteen songs were recorded by this singer and found to contain the same changes of pitch which marked the performance of the Acoma singer. In some songs the pitch was steadily maintained, while in others it was gradually raised or lowered a semitone during the first rendition, the remainder of the performance being on the new pitch.

John Smoke is an industrious Winnebago farmer, who retains a "water-spirit bundle" inherited from his ancestors and uses it in a ceremonial manner. He allowed Miss Densmore to see this bundle, explained its use and benefits, and recorded two of its songs which are sung when its contents are exposed to view. A Winnebago flute player known as Frisk Cloud recorded three melodies on a flute made of metal pipe, and said "the love songs are words put to flute melodies." He is also a maker of flutes and described the measurements of an instrument in terms of hand and finger widths and hand spreads. Miss Densmore purchased the instrument on which the melodies had been played.

Winnebago songs and another flute performance were recorded by George Monegar, a blind man living near Wisconsin Rapids, who is considered one of the best authorities on old customs. He also related the legend of the origin of the flute.

Songs of 10 classes were recorded on this trip, with old and modern examples of one class. The recorded songs comprise those of the water-spirit bundle, hand game, and moccasin game, love songs, war songs, and a lullaby, and songs of the Green Corn, Friendship, Fortynine, and Squaw dances.

At the suggestion of Senator Carl Hayden, Mr. Neil M. Judd, curator of archeology in the United States National Museum, made a brief reconnaissance in September, 1929, for the purpose of ascertaining the most practicable method of surveying, at this late date, the prehistoric canal systems of the Gila and Salt River Valleys, Ariz. Most of the ancient canals had been obliterated through agricultural practices; others were threatened with early destruction under the program of the Coolidge Dam project. Following his preliminary investigation, he recommended an aerial survey as the only feasible means whereby the former aboriginal canal systems could be located and mapped for permanent record.

Since haste was a prime factor, in view of the extensive grading operations within the Pima Indian Reservation, the War Department generously came to the aid of the Smithsonian Institution by providing an observation plane and personnel. Mr. Judd left Washington January 12, 1930, and proceeded to Phoenix, Ariz., by way of Tucson and Sacaton. Unfavorable flying conditions served to delay inauguration of the survey. Ground haze in the early morning and smoke in the afternoon obscured the ground except for a 2-hour period at mid-day. Lieut. Edwin Bobzien, pilot, and Sergt. R. A. Stockwell, photographer, both from Crissy Field, the Presidio, San Francisco, pursued their assigned tasks as rapidly as possible. They made approximately 700 exposures, of which half were vertical photographs taken from an altitude of 10,000 feet. These have since been assembled into mosaic maps. As was anticipated, the aerial survey disclosed numerous prehistoric canals not visible from the ground. With the mosaic maps in hand these ancient canals must now be examined individually and their locations identified with reference to nearby section lines. This task properly should be done during the late autumn or winter months and within the next few years.

Without the personal interest of Senator Hayden and the cooperation of the War Department, the Smithsonian Institution would have found it impossible to undertake the aerial survey above mentioned.

In late November, 1929, and again in early May, 1930, Mr. Judd made brief visits to Charlottesville, Va., there to advise with Mr. D. I. Bushnell, jr., in those investigations of nearby Indian village sites he is pursuing in behalf of the bureau.

### EDITORIAL WORK AND PUBLICATIONS

The editing of the publications of the bureau was continued through the year by Mr. Stanley Searles, editor, assisted by Mrs. Frances S. Nichols, editorial assistant. The status of the publications is presented in the following summary.

PUBLICATIONS ISSUED

Bulletin 88. Myths and Tales of the Southeastern Indians. (Swanton). x+275 pp.
Bulletin 90. Papago Music (Densmore). xx+229 pp. 19 pls. 4 figs.
Bulletin 91. Additional Studies of the Arts, Crafts, and Customs of the Guiana Indians (Roth). xvii+110 pp. 34 pls. 90 figs.
Bulletin 93. Pawnee Music (Densmore). xviii+129 pp. 8 pls.
Bulletin 95. Contributions to Fox Ethnology—II (Michelson). vii+183 pp. 1 fig.
List of Publications of the Bureau of American Ethnology. 50 pp.

PUBLICATIONS IN PRESS

Forty-fifth Annual Report. Accompanying papers: The Salishan Tribes of the Western Plateaus (Teit, edited by Boas); Tattooing and Face and Body Painting of the Thompson Indians, British Columbia (Teit, edited by Boas); The Ethnobotany of the Thompson Indians of British Columbia (Steedman); The Osage Tribe: Rite of the Wa-xó-be (La Flesche).
Forty-sixth Annual Report. Accompanying papers: Anthropological Survey in Alaska (Hrdlicka); Report to the Hon. Isaac S. Stevens, Governor of Washington Territory, on the Indian Tribes of the Upper Missouri (Denig, edited by Hewitt).
Bulletin 94. Tobacco among the Karuk Indians of California (Harrington).
Bulletin 96. Early Pueblo Ruins in the Piedra District, Southwestern Colorado (Roberts).

DISTRIBUTION OF PUBLICATIONS

The distribution of the publications of the bureau has been continued under the charge of Miss Helen Munroe, assisted by Miss Emma B. Powers. Publications distributed were as follows:

| | |
|---|---|
| Report volumes and separates | 3,938 |
| Bulletins and separates | 20,242 |
| Contributions to North American Ethnology | 40 |
| Miscellaneous publications | 648 |
| Total | 24,868 |

As compared with the fiscal year ended June 30, 1929, there was an increase of 4,756 publications distributed, due in part to the large number of separates from the Handbook of American Indians sent to Camp Fire Girls. After revision, the mailing list now stands at 1,627.

ILLUSTRATIONS

Following is a summary of work accomplished in the illustration branch of the bureau under the supervision of Mr. DeLancey Gill, illustrator:

| | |
|---|---|
| Photographs retouched, lettered, and otherwise made ready for engraving | 1,638 |
| Drawings prepared, including maps, charts, etc | 32 |
| Engravers' proofs criticized | 742 |

| | |
|---|---|
| Printed editions of colored plates examined at Government Printing Office | 31,500 |
| Correspondence attended to (letters) | 210 |
| Photographs selected and catalogued for private publishers | 314 |
| Photo-laboratory work by Dr. A. J. Olmsted, National Museum, in cooperation with the Bureau of American Ethnology: | |
| Negatives | 84 |
| Prints | 253 |
| Lantern slides | 23 |

## LIBRARY

The reference library has continued under the care of Miss Ella Leary, librarian, assisted by Mr. Thomas Blackwell.

The library consists of 29,071 volumes, about 16,527 pamphlets, and several thousand unbound periodicals. During the year 559 books were accessioned, of which 109 were acquired by purchase and 450 by gift and exchange; also 150 pamphlets, and 4,106 serials, chiefly the publications of learned societies, were received and recorded, of which 110 were obtained by purchase, the remainder being received through exchange. The catalogue was increased by the addition of 3,420 cards. Volumes to the number of 210 were collated and prepared for binding. Numerous loans were made to libraries in Washington, and a considerable amount of reference work was done in the usual course of the library's service to investigators and students, both those in the Smithsonian Institution and others. The purchase of books and periodicals for the library has been restricted to such as relate to the bureau's researches.

Many volumes received by the library not pertaining to anthropology were transferred to the library of the Smithsonian Institution. During the year the cataloguing has been carried on as new accessions were acquired and good progress was made in cataloguing ethnologic and related articles in the earlier serials. The number of books borrowed from the Library of Congress for the use of the staff of the bureau in prosecuting their researches was about 150.

## COLLECTIONS

Accession No.

107862. Archaic black and white bowl collected by Doctor Fewkes from Far View House, Mesa Verde, in 1921, and fragment of ancient Zuñi pottery from Canyon del Muerto, Ariz., collected by Dr. W. H. Spinks. (2 specimens.)

107866. Blackberrying basket made by Mrs. Ascensión Solórsano, a San Juan Indian, and collected by J. P. Harrington in 1929. (1 specimen.)

109074. Flint hammerstone presented to the bureau by J. D. Howard; cast of an engraved bone gorget sent by E. M. Graves; and a Chinese basket. (3 specimens.)

Accession No.

109788. Smoking pipe or cigarette made of anis by the San Juan Indians, San Benito County, Calif., and collected by J. P. Harrington. (1 specimen.)

110111. Cast of a "cogged" stone from the ranch of Mrs. Newland of Huntington Beach, Los Angeles, Calif., and presented to the bureau by S. C. Evans. (1 specimen.)

110113. Decorated elk-skin pouch made by Fritz Hanson, a Karuk Indian of Somesbar, Siskiyou Co., Calif., and purchased from him by the bureau. (1 specimen.)

110319. Archeological material collected in 1928 by Dr. F. H. H. Roberts, jr., from early Pueblo ruins in the Piedra District, Archuleta Co., southwest Colorado. (477 specimens.)

PROPERTY

Office equipment was purchased to the amount of $64.78.

MISCELLANEOUS

The correspondence and other clerical work of the office has been conducted by Miss May S. Clark, clerk to the chief, assisted by Mr. Anthony W. Wilding, clerk. Miss Mae W. Tucker, stenographer, was engaged in completing the catalogue of phonograph records of Indian music, copying manuscripts for Doctor Swanton and in assisting Mr. Hewitt in his work as custodian of manuscripts and phonograph records. Mrs. Frances S. Nichols assisted the editor.

During the course of the year information was furnished by members of the staff in reply to numerous inquiries concerning the North American Indian peoples, both past and present, and the Mexican peoples of the prehistoric and early historic periods to the south. Various specimens sent to the bureau were identified and data on them furnished for their owners.

*Personnel*—Dr. Francis LaFlesche retired as ethnologist of the bureau December 26, 1929.

Respectfully submitted.

M. W. Stirling, *Chief.*

Dr. C. G. Abbot,
*Secretary, Smithsonian Institution.*

# APPENDIX 5

## REPORT ON THE INTERNATIONAL EXCHANGE SERVICE

SIR: I have the honor to submit the following report on the operations of the International Exchange Service during the fiscal year ending June 30, 1930:

For the support of the system of International Exchanges Congress appropriated $51,297, an increase of $942 over the amount granted for the preceding year. This extra amount was requested to cover the added cost for freight due to the increase in the weight of shipments sent abroad. The repayments from governmental and other establishments aggregated $5,050.30, making the total resources available for carrying on the Exchange Service during 1930, $56,347.30.

The total number of packages received both from domestic and foreign sources for distribution through the service was 694,665, an increase over the previous year of 74,180, or about 12 per cent. The weight of these packages was 708,094 pounds, a gain of 86,721 pounds, or nearly 14 per cent. These increases are quite out of the ordinary, especially when it is considered that the gain in packages during the preceding year was one of the largest in the history of the service.

The publications sent and received by the Exchange Service are classified as parliamentary documents, departmental documents, and miscellaneous scientific and literary publications. The term "Parliamentary documents," as here used, refers to publications set aside by law for exchange with foreign governments, and includes not only documents printed by order of either House of Congress, but those issued by any department, bureau, or commission of the Government not of a confidential nature. The returns for these publications are deposited in the Library of Congress. The term "Departmental documents" embraces all of the publications delivered at the Institution from the various Government departments, bureaus, or commissions, for distribution to correspondents abroad from whom they desire to obtain similar publications in exchange. The "Miscellaneous scientific and literary publications" are received chiefly from learned societies, universities, colleges, scientific organizations, and museums. The number and weight of packages coming under these different headings are as follows:

| | Packages | | Weight | |
|---|---|---|---|---|
| | Sent | Received | Sent | Received |
| | | | *Pounds* | *Pounds* |
| United States parliamentary documents sent abroad | 298, 833 | | 134, 829 | |
| Publications received in return for parliamentary documents | | 13, 511 | | 35, 597 |
| United States departmental documents sent abroad | 196, 917 | | 185, 394 | |
| Publications received in return for departmental documents | | 7, 079 | | 25, 065 |
| Miscellaneous scientific and literary publications sent abroad | 127, 166 | | 217, 890 | |
| Miscellaneous scientific and literary publications received from abroad for distribution in the United States | | 51, 159 | | 109, 319 |
| Total | 622, 916 | 71, 749 | 538, 113 | 169, 981 |
| Grand total | 694, 665 | | 708, 094 | |

It will be seen from the foregoing table that 74 per cent of the work of the office has been conducted in behalf of the United States governmental establishments.

There were shipped abroad during the year 3,235 boxes, being an increase of 412 (14.6 per cent) over the number for the preceding 12 months. This is the largest number of boxes forwarded abroad through the service in one year. These boxes measured a total of 17,034 cubic feet. Seven hundred and eighty-five of the boxes contained full sets of United States official documents for authorized depositories and the remainder (2,450) were filled with departmental and other publications for depositories of partial sets and for miscellaneous correspondents. The number of boxes sent to each country is given below:

*Consignments of exchanges forwarded to foreign countries*

| Country | Number of boxes | Country | Number of boxes |
|---|---|---|---|
| Argentina | 71 | Japan | 90 |
| Austria | 63 | Latvia | 26 |
| Belgium | 72 | Mexico | 13 |
| Bolivia | 3 | Netherlands | 84 |
| Brazil | 53 | New South Wales | 37 |
| British Colonies | 29 | New Zealand | 41 |
| Bulgaria | 9 | Norway | 55 |
| Canada | 52 | Palestine | 107 |
| Chile | 33 | Paraguay | 2 |
| China | 76 | Peru | 27 |
| Colombia | 28 | Poland | 49 |
| Costa Rica | 32 | Portugal | 27 |
| Cuba | 13 | Queensland | 28 |
| Czechoslovakia | 68 | Rumania | 26 |
| Danzig | 2 | Russia | 150 |
| Denmark | 48 | Siam | 4 |
| Ecuador | 8 | South Australia | 27 |
| Egypt | 25 | Spain | 44 |
| Estonia | 27 | Sweden | 98 |
| Finland | 18 | Switzerland | 93 |
| France | 197 | Tasmania | 22 |
| Germany | 376 | Turkey | 13 |
| Great Britain and Ireland | 390 | Union of South Africa | 54 |
| Greece | 4 | Uruguay | 28 |
| Haiti | 3 | Venezuela | 24 |
| Honduras | 2 | Victoria | 74 |
| Hong Kong | 1 | Western Australia | 26 |
| Hungary | 43 | Yugoslavia | 29 |
| India | 73 | | |
| Italy | 118 | Total | 3, 235 |

In addition to the packages forwarded abroad in boxes, 67,945—an increase over last year of 7,089—were sent to their destinations direct by mail. About one-third of these packages contained copies of the daily issue of the Congressional Record, which, under treaty stipulations and by authority of Congress, are mailed directly to the depositories immediately upon publication. The remainder of the packages were partly for remote places which could not be reached through existing agencies and partly for countries for which the accumulations were so small at the scheduled forwarding dates that it was more economical to send them by mail than by freight.

Almost since the establishment of the Smithsonian system of exchanges in 1850, consignments received from abroad have, at the request of the Institution, been addressed in care of the collector of customs at the port of New York, consignments so addressed being admitted duty free and without examination. Up to July 1, 1923, an official of the United States customhouse attended to the entry and transmission to Washington of shipments arriving at the port of New York for the Smithsonian Institution. On that date the coordinator of the second area assumed charge of the handling of all shipments for the Institution, both incoming and outgoing. However, as the foreign agencies had for so many years been accustomed to addressing boxes to the Institution in care of the Collector of Customs, no change in that regard was made until shortly before the close of the current fiscal year, when the various foreign exchange bureaus were requested to address all future shipments to the Institution as follows:

SMITHSONIAN INSTITUTION,
Washington, D. C.
Care Coordinator, Second Area,
Customhouse, New York City, U. S. A.

During the year nine boxes of exchanges from Germany were destroyed when the steamship *München* sunk while unloading at her pier in New York, the sinking of the vessel having been caused by an explosion which resulted in a fire. These boxes contained publications for distribution to various addresses in the United States and German patent specifications for the United States Patent Office, Boston Public Library, Chicago Public Library, and St. Louis Public Library. An effort is being made to obtain duplicate copies of the lost publications.

As an example of the use made of the facilities of the International Exchange Service other than in transporting packages, reference is made to a request from Adelbert College Library, Cleveland, Ohio, for information concerning the Bulletin of Works published by the Station of Aquiculture and Fisheries of Castiglione, a communication regarding the matter addressed to the station itself by the

library not having received attention. Full information was obtained by this office through the French Exchange Bureau, and in the library's letter of acknowledgment to the Institution it is stated that "the information, which had been impossible for us to obtain, is just what we need."

### FOREIGN DEPOSITORIES OF GOVERNMENTAL DOCUMENTS

A convention for the international exchange of official documents and scientific and literary publications was concluded at Brussels March 15, 1886, between the United States and certain other countries. In accordance with the terms of that convention and under authority of resolutions of Congress setting apart a certain number of documents for exchange with foreign governments, there now are sent regularly to depositories abroad 62 full sets of United States official publications and 47 partial sets, an increase of four sets during the year. China, Assam, Bihar and Orissa, Central Provinces, and the Punjab were added to the list of those countries receiving partial sets, and the set sent to Lourenço Marquez was discontinued.

The depository in Austria has been changed from the Bundesamt für Statistik to the Bundeskanzleramt, Herrengasse 23, Vienna I; the one in Bolivia from the Ministerio de Colonización y Agricultura to the Biblioteca del H. Congreso Nacional, La Paz; the one in Hesse, Germany, from the Landesbibliothek, Darmstadt, to the Universitäts-Bibliothek, Giessen; and the one in Honduras from the Ministerio de Relaciones Exteriores to the Biblioteca y Archivo Nacionales, Tegucigalpa.

A complete list of the foreign depositories of governmental documents is given below:

#### DEPOSITORIES OF FULL SETS

ARGENTINA: Ministerio de Relaciones Exteriores, Buenos Aires.
BUENOS AIRES: Biblioteca de la Universidad Nacional de La Plata, La Plata. (Depository of the Province of Buenos Aires.)
AUSTRALIA: Library of the Commonwealth Parliament, Canberra.
NEW SOUTH WALES: Public Library of New South Wales, Sydney.
QUEENSLAND: Parliamentary Library, Brisbane.
SOUTH AUSTRALIA: Parliamentary Library, Adelaide.
TASMANIA: Parliamentary Library, Hobart.
VICTORIA: Public Library of Victoria, Melbourne.
WESTERN AUSTRALIA: Public Library of Western Australia, Perth.
AUSTRIA: Bundeskanzleramt, Herrengasse 23, Vienna I.
BELGIUM: Bibliothèque Royale, Brussels.
BRAZIL: Bibliotheca Nacional, Rio de Janeiro.
CANADA: Library of Parliament, Ottawa.
MANITOBA: Provincial Library, Winnipeg.
ONTARIO: Legislative Library, Toronto.
QUEBEC: Library of the Legislature of the Province of Quebec, Quebec.

CHILE: Biblioteca del Congreso Nacional, Santiago.
CHINA: Ministry of Foreign Affairs, Nanking.
COLOMBIA: Biblioteca Nacional, Bogotá.
COSTA RICA: Oficina de Depósito y Canje International de Publicaciones, San José.
CUBA: Secretaría de Estado (Asuntos Generales y Canje Internacional), Habana.
CZECHOSLAVAKIA: Bibliothèque de l'Assemblée Nationale, Prague.
DENMARK: Kongelige Bibliotheket, Copenhagen.
EGYPT: Bureau des Publications, Ministère des Finances, Cairo.
ESTONIA: Riigiraamatukogu (State Library), Tallinn (Reval).
FRANCE: Bibliothèque Nationale, Paris.
PARIS: Préfecture de la Seine.
GERMANY: Reichstauschstelle im Reichsministerium des Innern, Berlin C 2.
BADEN: Universitäts-Bibliothek, Freiburg. (Depository of the State of Baden.)
BAVARIA: Bayerische Staatsbibliothek, Munich.
PRUSSIA: Preussische Staatsbibliothek, Berlin, N. W. 7.
SAXONY: Sächsische Landesbibliothek, Dresden—N. 6.
WURTEMBERG: Landesbibliothek, Stuttgart.
GREAT BRITAIN:
ENGLAND: British Museum, London.
GLASGOW: City Librarian, Mitchell Library, Glasgow.
LONDON: London School of Economics and Political Science. (Depository of the London County Council.)
GREECE: Shipments temporarily suspended.
HUNGARY: Hungarian House of Delegates, Budapest.
INDIA: Imperial Library, Calcutta.
IRISH FREE STATE: National Library of Ireland, Dublin.
ITALY: Ministero della Pubblica Istruzione, Rome.
JAPAN: Imperial Library of Japan, Tokyo.
LATVIA: Bibliothèque d'État, Riga.
MEXICO: Biblioteca Nacional, Mexico, D. F.
NETHERLANDS: Royal Library, The Hague.
NEW ZEALAND: General Assembly Library, Wellington.
NORTHERN IRELAND: Ministry of Finance, Belfast.
NORWAY: Universitets-Bibliotek, Oslo. (Depository of the Government of Norway.)
PERU: Biblioteca Nacional, Lima.
POLAND: Bibliothèque du Ministère des Affaires Étrangères, Warsaw.
PORTUGAL: Biblioteca Nacional, Lisbon.
RUMANIA: Academia Română, Bucharest.
RUSSIA: Shipments temporarily suspended.
SPAIN: Servicio del Cambio Internacional de Publicaciones, Cuerpo Facultativo de Archiveros, Bibliotecarios y Arqueólogos, Madrid.
SWEDEN: Kungliga Biblioteket, Stockholm.
SWITZERLAND: Bibliothèque Centrale Fédérale, Berne.
SWITZERLAND: Library of the League of Nations, Geneva.
TURKEY: Ministère de l'Instruction Publique, Angora.
UNION OF SOUTH AFRICA: State Library, Pretoria, Transvaal.
URUGUAY: Oficina de Canje Internacional de Publicaciones, Montevideo.
VENEZUELA: Biblioteca Nacional, Caracas.
YUGOSLAVIA: Ministère de l'Éducation, Belgrade.

DEPOSITORIES OF PARTIAL SETS

AUSTRIA:
VIENNA: Wiener Magistrat.
BOLIVIA: Biblioteca del H. Congreso Nacional, La Paz.
BRAZIL:
MINAS GERAES: Directoria Geral de Estatistica em Minas, Bello Horizonte, Minas Geraes.
RIO DE JANEIRO: Bibliotheca da Assemblea Legislativa do Estado, Nictheroy.
BRITISH GUIANA: Government Secretary's Office, Georgetown, Demerara.
BULGARIA: Ministère des Affaires Étrangères, Sofia.
CANADA:
ALBERTA: Provincial Library, Edmonton.
BRITISH COLUMBIA: Legislative Library, Victoria.
NEW BRUNSWICK: Legislative Library, Fredericton.
NOVA SCOTIA: Provincial Secretary of Nova Scotia, Halifax.
PRINCE EDWARD ISLAND: Legislative Library, Charlottetown.
SASKATCHEWAN: Government Library, Regina.
CEYLON: Colonial Secretary's Office (Record Department of the Library), Colombo.
CHINA: National Library, Peiping.
DANZIG: Stadtbibliothek, Free City of Danzig.
DOMINICAN REPUBLIC: Biblioteca del Senado, Santo Domingo.
ECUADOR: Biblioteca Nacional, Quito.
FINLAND: Parliamentary Library, Helsingfors.
FRANCE:
ALSACE-LORAINE: Bibliothèque Universitaire et Régionale de Strasbourg, Strasbourg.
GERMANY:
BREMEN: Senatskommission für Reichs- und Auswärtige Angelegenheiten.
HAMBURG: Senatskommission für Reichs- und Auswärtige Angelegenheiten.
HESSE: Universitäts-Bibliothek, Giessen.
LÜBECK: President of the Senate.
THURINGIA: Rothenberg-Bibliothek, Landesuniversität, Jena.
GUATAMALA: Secretaria de Relaciones Exteriores de la República de Guatemala.
HAITI: Secrétaire d'État des Relations Extérieures, Port au Prince.
HONDURAS: Biblioteca y Archivo Nacionales, Tegucigalpa.
ICELAND: National Library, Reykjavik.
INDIA:
ASSAM: General and Judicial Department, Shillong.
BIHAR and ORISSA: Revenue Department, Patna.
BOMBAY: Undersecretary to the Government of Bombay, General Department, Bombay.
BURMA: Secretary to the Government of Burma, Education Department, Rangoon.
CENTRAL PROVINCES: General Administration Department, Nagpur.
MADRAS: Chief Secretary to the Government of Madras, Public Department, Madras.
PUNJAB: Chief Secretary to the Government of the Punjab, Lahore.
UNITED PROVINCES OF AGRA AND OUDH: University of Allahabad, Allahabad.
JAMAICA: Colonial Secretary, Kingston.
LIBERIA: Department of State, Monrovia.

LITHUANIA: Ministère des Affaires Étrangères, Kaunas (Kovno).
MALTA: Minister for the Treasury, Valetta.
NEWFOUNDLAND: Colonial Secretary, St. Johns.
NICARAGUA: Superintendente de Archivos Nacionales, Managua.
PANAMA: Secretaría de Relaciones Exteriores, Panama.
PARAGUAY: Sección Canje Internacional de Publicaciones del Ministerio de Relaciones Exteriores, Estrella, 563, Asunción.
SALVADOR: Ministerio de Relaciones Exteriores, San Salvador.
SIAM: Department of Foreign Affairs, Bangkok.
STRAITS SETTLEMENTS: Colonial Secretary, Singapore.

### INTERPARLIAMENTARY EXCHANGE OF THE OFFICIAL JOURNAL

In 1909 Congress, in order to more fully carry into effect the provisions of the exchange convention concluded at Brussels in 1886, passed a resolution setting aside a certain number of copies of the daily issue of the Congressional Record for exchange, through the Smithsonian Institution, with such foreign governments as may agree to send to the United States current copies of their parliamentary record or like publication, the returns to be deposited in the Library of Congress. Since the passage of that resolution many countries have entered into this exchange, 102 copies of the Record now being sent abroad, one new depository—Colonial Secretary, Belize, British Honduras—having been added during the year.

The depositories of the Record in San José, Costa Rica; Port-au-Prince, Haiti; and Belgrade, Yugoslavia, have been discontinued and the following have been added: "A Federação," Porto Alegre, Brazil; Ufficio degli Studi Legislativi, Rome, Italy; Library of the Persian Parliament, Teheran, Persia. The depository in Madrid, Spain has been changed to Biblioteca del Congreso Nacional.

A complete list of the States taking part in this immediate exchange, together with the names of the establishments to whom the Record is mailed, is given below:

#### DEPOSITORIES OF CONGRESSIONAL RECORD

ARGENTINA:
Biblioteca del Congreso Nacional, Buenos Aires.
Cámara de Diputados, Oficina de Información Parlamentaria, Buenos Aires.
Buenos Aires: Biblioteca del Senado de la Provincia de Buenos Aires, La Plata.

AUSTRALIA:
Library of the Commonwealth Parliament, Canberra.
New South Wales: Library of Parliament of New South Wales, Sydney.
Queensland: Chief Secretary's Office, Brisbane.
Western Australia: Library of Parliament of Western Australia, Perth.

AUSTRIA: Bibliothek des Nationalrates, Vienna I.
BELGIUM: Bibliothèque de la Chambre des Représentants, Brussels.
BOLIVIA: Biblioteca del H. Congreso Nacional, La Paz.

BRAZIL:
Bibliotheca do Congresso Nacional, Rio de Janeiro.
Amazonas: Archivo, Bibliotheca e Imprensa Publica, Manãos.
Bahia: Governador do Estado de Bahia, São Salvador.
Espirito Santo: Presidencia do Estado do Espirito Santo, Victoria.
Rio Grande do Sul: "A Federação," Porto Alegre.
Sergipe: Director da Imprensa Official, Aracaju.
São Paulo: Diario Official do Estado de São Paulo, São Paulo.
BRITISH HONDURAS: Colonial Secretary, Belize.
CANADA:
Library of Parliament, Ottawa.
Clerk of the Senate, Houses of Parliament, Ottawa.
CHINA: National Library, Pei Hai, Peking.
CUBA:
Biblioteca de la Cámara de Representantes, Habana.
Biblioteca del Senado, Habana.
CZECHOSLOVAKIA: Bibliothèque de l'Assemblée Nationale, Prague.
DANZIG: Stadtbibliothek, Danzig.
DENMARK: Rigsdagens Bureau, Copenhagen.
DOMINICAN REPUBLIC: Biblioteca del Senado, Santo Domingo.
DUTCH EAST INDIES: Volksraad von Nederlandsch-Indië, Batavia, Java.
EGYPT: Bureau des Publications, Ministère des Finances, Cairo.
ESTONIA: Riigiraamatukogu (State Library), Tallinn (Reval).
FRANCE:
Chambre des Députés, Service de l'Information Parlementaire Étrangère, Paris.
Bibliothèque du Sénat, au Palais du Luxembourg, Paris.
GERMANY:
Deutsche Reichstags-Bibliothek, Berlin, N. W. 7.
Anhalt: Anhaltische Landesbücherei, Dessau.
Baden: Universitäts-Bibliothek, Heidelberg.
Braunschweig: Bibliothek des Braunschweigischen Staatsministeriums, Braunschweig.
Mecklenburg-Schwerin: Staatsministerium, Schwerin.
Mecklenburg-Strelitz: Finanzdepartement des Staatsministeriums, Neustrelitz.
Oldenburg: Oldenburgisches Staatsministerium, Oldenburg i. O.
Prussia: Bibliothek des Abgeordnetenhauses, Prinz-Albrechtstrasse 5, Berlin, S. W. 11.
Schaumburg-Lippe: Schaumburg-Lippische Landesregierung, Bücheburg.
GIBRALTAR: Gibraltar Garrison Library Committee, Gibraltar.
GREAT BRITAIN: Library of the Foreign Office, London.
GREECE: Library of Parliament, Athens.
GUATEMALA: Archivo General del Gobierno, Guatemala.
HONDURAS: Biblioteca del Congreso Nacional, Tegucigalpa.
HUNGARY: Bibliothek des Abgeordnetenhauses, Budapest.
INDIA: Legislative Department, Simla.
ITALY:
Biblioteca della Camera dei Deputati, Rome.
Biblioteca del Senato del Regno, Rome.
Ufficio degli Studi Legislativi, Santo del Regno. Rome.

IRAQ: Chamber of Deputies, Baghdad, Iraq (Mesopotamia).
IRISH FREE STATE: Dail Eireann, Dublin.
LATVIA: Library of the Saeima, Riga.
LIBERIA: Department of State, Monrovia.
MEXICO: Secretaria de la Cámara de Diputados, Mexico, D. F.
Aguascalientes: Gobernador del Estado de Aguascalientes, Aguascalientes.
Campeche: Gobernador del Estado de Campeche, Campeche.
Chihuahua: Gobernador del Estado de Chihuahua, Chihuahua.
Chiapas: Gobernador del Estado de Chiapas, Tuxtla Gutierrez.
Coahuila: Periódico Oficial del Estado de Coahuila, Palacio de Gobierno, Saltillo.
Colima: Gobernador del Estado de Colima, Colima.
Durango: Gobernador Constitucional del Estado de Durango, Durango.
Guanajuato: Secretaría General de Gobierno del Estado, Guanajuato.
Guerrero: Gobernador del Estado de Guerrero, Chilpancingo.
Jalisco: Biblioteca del Estado, Guadalajara.
Lower California: Gobernador del Distrito Norte, Mexicali, B. C., Mexico.
Mexico: Gaceta del Gobierno, Toluca, Mexico.
Michoacán: Secretaría General de Gobierno del Estado de Michoacán, Morelia.
Morelos: Palacio de Gobierno, Cuernavaca.
Nayarit: Gobernador de Nayarit, Tepic.
Nuevo León: Biblioteca del Estado, Monterey.
Oaxaca: Periódico Oficial, Palacio de Gobierno, Oaxaca.
Puebla: Secretaría General de Gobierno, Zaragoza.
Queretaro: Secretaría General de Gobierno, Sección de Archivo, Queretaro.
San Luis Potosi: Congreso del Estado, San Luis Potosi.
Sinaloa: Gobernador del Estado de Sinaloa, Culiacan.
Sonora: Gobernador del Estado de Sonora, Hermosillo.
Tabasco: Secretaría General de Gobierno, Sección 3a, Ramo de Prensa, Villahermosa.
Tamaulipas: Secretaría General de Gobierno, Victoria.
Tlaxcala: Secretaría de Gobierno del Estado, Tlaxcala.
VERA CRUZ: Gobernador del Estado de Vera Cruz, Departamento de Gobernación y Justicia, Jalapa.
Yucatán: Gobernador del Estado de Yucatán, Mérida, Yucatán.
NEW ZEALAND: General Assembly Library, Wellington.
NORWAY: Storthingets Bibliothek, Oslo.
PERSIA: Library of the Persian Parliament, Téhéran.
PERU: Cámara de Diputados, Congreso Nacional, Lima.
POLAND: Ministère des Affaires Étrangères, Warsaw.
PORTUGAL: Biblioteca do Congresso da Republica, Lisbon.
RUMANIA:
Bibliothèque de la Chambre des Députés, Bucharest.
Ministère des Affaires Étrangères, Bucharest.
SPAIN:
Biblioteca del Congreso Nacional, Madrid.
Barcelona: Biblioteca de la Comisión Permanente Provincial de Barcelona, Barcelona.
SWITZERLAND:
Bibliothèque de l'Assemblée Fédérale Suisse, Berne.
Library of the League of Nations, Geneva.

SYRIA:
Ministère des Finances de la République Libanaise, Service du Matériel, Beirut.
Governor of the State of Alaouites, Lattaquié.
TURKEY: Turkish Grand National Assembly, Angora.
UNION OF SOUTH AFRICA:
Library of Parliament, Cape Town, Cape of Good Hope.
State Library, Pretoria, Transvaal.
URUGUAY: Biblioteca de la Cámara de Representantes, Montevideo.
VENEZUELA: Cámara de Diputados, Congreso Nacional, Carácas.

## FOREIGN EXCHANGE AGENCIES

Following is a list of bureaus or agencies abroad through which the distribution of exchanges is effected. Most of those agencies forward consignments to the Smithsonian Institution for distribution in the United States.

### LIST OF EXCHANGE AGENCIES

ALGERIA, via France.
ANGOLA, via Portugal.
ARGENTINA: Comisión Protectora de Bibliotecas Populares, Calle Córdoba 931, Buenos Aires.
AUSTRIA: Internationale Austauschstelle, Bundeskanzleramt, Herrengasse 23, Vienna I.
AZORES, via Portugal.
BELGIUM: Service Belge de Échanges Internationaux, Rue des Longs-Chariots, 46, Brussels.
BOLIVIA: Oficina Nacional de Estadistica, La Paz.
BRAZIL: Servicio de Permutações Internacionaes, Bibliotheca Nacional, Rio de Janeiro.
BRITISH COLONIES: Crown Agents for the Colonies, London.
BRITISH GUIANA: Royal Agricultural and Commercial Society, Georgetown.
BRITISH HONDURAS: Colonial Secretary, Belize.
BULGARIA: Institutions Scientifiques de S. M. le Roi de Bulgarie, Sofia.
CANARY ISLANDS, via Spain.
CHILE: Servicio de Canjes Internacionales, Biblioteca Nacional, Santiago.
CHINA: Bureau of International Exchange, Academia Sinica, 205 Avenue du Roi Albert, Shanghai.
COLOMBIA: Oficina de Canjes Internacionales y Reparto, Biblioteca Nacional, Bogotá.
COSTA RICA: Oficina de Depósito y Canje International de Publicaciones, San José.
CZECHOSLOVAKIA: Service Tchécoslovaque des Échanges Internationaux, Bibliothèque de l'Assemblée Nationale, Prague 1–79.
DANZIG: Amt für den Internationalen Schriftenaustausch der Freien Stadt Danzig, Stadtbibliothek, Danzig.
DENMARK: Service Danois des Échanges Internationaux, Kongelige Danske Videnskabernes Selskab, Copenhagen.
DUTCH GUIANA: Surinaamsche Koloniale Bibliotheek, Paramaribo.
ECUADOR: Ministerio de Relaciones Exteriores, Quito.

EGYPT: Bureau des Publications, Ministère des Finances, Cairo.
ESTONIA: Riigiraamatukogu (State Library), Tallinn (Reval).
FINLAND: Delegation of the Scientific Societies of Finland, Helsingfors.
FRANCE: Service Français des Échanges Internationaux, 110 Rue de Grenelle, Paris.
GERMANY: Amerika-Institut, Universitätstrasse 8, Berlin, N. W. 7.
GREAT BRITAIN AND IRELAND: Messrs. Wheldon & Wesley, 2, 3, and 4 Arthur St., New Oxford St., London W. C. 2.
GREECE: Bibliothèque Nationale, Athens.
GREENLAND, via Denmark.
GUATEMALA: Instituto Nacional de Varones, Guatemala.
HAITI: Secrétaire d'État des Relations Extérieures, Port-au-Prince.
HONDURAS: Biblioteca Nacional, Tegucigalpa.
HUNGARY: Hungarian Libraries Board, Budapest, IV.
ICELAND, via Denmark.
INDIA: Superintendent of Stationery, Bombay.
ITALY: R. Ufficio degli Scambi Internazionali, Ministero della Pubblica Istruzione, Rome.
JAMAICA: Institute of Jamaica, Kingston.
JAPAN: Imperial Library of Japan, Tokyo.
JAVA, via Netherlands.
KOREA: Government General, Seoul.
LATVIA: Service des Échanges Internationaux, Bibliothèque d'État de Lettonie, Riga.
LIBERIA: Bureau of Exchanges, Department of State, Monrovia.
LITHUANIA: Sent by mail.
LOURENÇO MARQUEZ, via Portugal.
LUXEMBURG, via Belgium.
MADAGASCAR, via France.
MADEIRA, via Portugal.
MOZAMBIQUE, via Portugal.
NETHERLANDS: International Exchange Bureau of the Netherlands, Royal Library, The Hague.
NEW SOUTH WALES: Public Library of New South Wales, Sydney.
NEW ZEALAND: Dominion Museum, Wellington.
NICARAGUA: Ministrio de Relaciones Exteriores, Managua.
NORWAY: Service Norvégien des Échanges Internationaux, Bibliothèque de l'Université Royale, Oslo.
PALESTINE: Hebrew University Library, Jerusalem.
PANAMA: Sent by mail.
PARAGUAY: Sección Canje Internacional de Publicaciones del Ministerio de Relaciones Exteriores, Estrella 563, Asuncion.
PERU: Oficina de Reparto, Depósito y Canje Internacional de Publicaciones, Ministerio de Fomento, Lima.
POLAND: Service Polonais des Échanges Internationaux, Bibliothèque du Ministère des Affaires Etrangères, Warsaw.
PORTUGAL: Secção de Trocas Internaciones, Biblioteca Nacional, Lisbon.
QUEENSLAND: Bureau of Exchanges of International Publications, Chief Secretary's Department, Brisbane.
RUMANIA: Bureau des Échanges Internationaux, Institut Météorologique Central, Bucharest.
RUSSIA: Academy of Sciences, Leningrad.
SALVADOR: Ministerio de Relaciones Exteriores, San Salvador.

SIAM: Department of Foreign Affairs, Bangkok.
SOUTH AUSTRALIA: South Australian Government Exchanges Bureau, Government Printing and Stationery Office, Adelaide.
SPAIN: Servicio del Cambio Internacional de Publicaciones, Cuerpo Facultativo de Archiveros, Bibliotecarios y Arqueólogos, Madrid.
SUMATRA, via Netherlands.
SWEDEN: Kongliga Svenska Vetenskaps Akademien, Stockholm.
SWITZERLAND: Service Suisse des Échanges Internationaux, Bibliothèque Centrale Fédérale, Berne.
SYRIA: American University of Beirut.
TASMANIA: Secretary to the Premier, Hobart.
TRINIDAD: Royal Victoria Institute of Trinidad and Tobago, Port-of-Spain.
TUNIS, via France.
TURKEY: Robert College, Constantinople.
UNION OF SOUTH AFRICA: Government Printing Works, Pretoria, Transvaal.
URUGUAY: Oficina de Canje Internacional de Publicaciones, Montevideo.
VENEZUELA: Biblioteca Nacional, Caracas.
VICTORIA: Public Library of Victoria, Melbourne.
WESTERN AUSTRALIA: Public Library of Western Australia, Perth.
YUGOSLAVIA: Ministère des Affaires Étrangères, Belgrade.

Mrs. Lucy C. Boehmer, who was retired in March last after having served for 34 years in the International Exchange Service, died July 2, 1930. She was the widow of George H. Boehmer, formerly chief clerk of the Exchange Service.

Respectfully submitted.

C. W. SHOEMAKER,
*Chief Clerk, International Exchange Service.*

Dr. CHARLES G. ABBOT,
*Secretary, Smithsonian Institution.*

# APPENDIX 6

## REPORT ON THE NATIONAL ZOOLOGICAL PARK

SIR: I have the honor to submit the following report on the operations of the National Zoological Park for the fiscal year ending June 30, 1930:

The regular appropriation made by Congress for the maintenance of the park was $203,000, an increase of $7,450 over 1929. In addition an appropriation of $220,000 was provided for the construction of a reptile house. The completion of this building has been made possible by the addition of $28,000 to the regular 1931 appropriation. The first deficiency act provided $2,000 for the construction of a gate to close at night a new road leading into the south portion of the park by Rock Creek.

On February 8, 1930, the Zoo suffered a severe loss in the death of Mr. A. B. Baker, who for more than 39 years had been assistant director. To Mr. Baker's great loyalty as well as his profound knowledge of zoological park management is due to a large extent the development of the National Zoological Park. His death takes away not only a good friend but a most valued official. He was succeeded by Mr. Ernest P. Walker, formerly senior biologist of the Biological Survey, who had recently been engaged in the game and bird reservation work conducted by that bureau.

### ACCESSIONS

*Gifts.*—The collection this year has been greatly benefited by gifts, some of them of rare and unusual specimens obtained on expeditions.

Dr. Paul Bartsch brought home with him from South America and the West Indies 6 iguanas, 10 South American tortoises, and 50 hermit crabs.

Mr. Fred Carnochan, of New York, returned from East Africa with a rare white-thighed colobus, a Schwineforth chimpanzee, and a Killimbira guenon. This last was obtained from M. de Freygang of Urundi, and is the first of its kind to be exhibited in the United States.

Mr. Stephen Haweis brought from Dominica four giant toads and half a dozen large edible frogs of this island, locally called "mountain chickens."

Dr. H. C. Kellers, United States Navy, who accompanied the astronomical expedition to the Philippines, returned with a large shipment of snakes, lizards, birds, and small mammals.

Mr. W. M. Perrygo of the United States National Museum, on an expedition to Haiti, secured a large collection, of which six rhinoceros iguanas and two Haitian boas were the most interesting to the Zoo, though some of the small snakes that he collected may prove to be new species.

Hon. Gifford Pinchot, who cruised the Pacific on a notable expedition, brought home with him for the National Zoological Park a specimen of the almost extinct Duncan Island tortoise, a Hood Island tortoise, four Albemarle tortoises, and three land iguanas, all from the Galapagos. These are very important additions and make the collection of giant tortoises one of the finest.

Through Theodore Roosevelt, jr., Harold S. Coolidge, jr., and Ralph Wheeler, of the Kelly-Roosevelt expedition, were presented a trio of white-faced gibbons, father, mother, and child, all magnificent specimens; a rare Bay Bamboo rat; a sun bear; a Himalayan bear; as well as several smaller specimens.

Mr. Foster H. Benjamin of the United States Department of Agriculture, who has been engaged in field work in connection with the extermination of the fruit fly in Florida, has kept a constant lookout for reptiles, and through him there has been obtained a notable collection of Florida species, including many desirable specimens.

Mr. O. Hallson, Bethel, Alaska, through the Alaska Game Commission and the United States Biological Survey, sent three pairs of the rare Emperor goose, and Mr. E. R. Kalmbach of the United States Biological Survey secured on a western trip a collection of 31 assorted birds, including 5 Caspian terns.

The United Fruit Co., through Mr. Samuel Kress of Costa Rica, has continued its interest and presented a fine pair of Costa Rican deer, a collared peccary, and an Imperial boa.

Through the Walter P. Chrysler fund was purchased a specimen of the very rare saddle-bill stork of West Africa, one of the most striking of living birds. This bird was captured by the Viennese explorer Weidholz, and was acclimatized in Vienna and afterwards in Nice.

DONORS

Mr. Eugene L. Abbott, Washington, D. C., alligator.

Mr. H. W. Armentrout, Washington, D. C., 6 opossums.

Dr. Paul Bartsch, National Museum, Washington, D. C., 6 iguanas, 10 tortoises, 50 hermit crabs.

Mr. Frank Bastiani, Washington, D. C., Cuban parrot.

Mr. D. F. Beale, Washington, D. C., ring-necked pheasant.

Mr. Foster H. Benjamin, Orlando, Fla., through United States Department of Agriculture, American "chameleon," 4 gopher tortoises, 2 chicken turtles, 4 Florida box turtles, 5 soft-shell turtles, Osceola snapping turtle, 2 pine snakes, worm lizard, indigo snake, 9 tree frogs, oak toad, 4 toads.

Mr. John L. Billman, Washington, D. C., horned lizard.

Mr. J. S. C. Boswell, Alexandria, Va., 2 copperheads, king snake, water snake.

Mrs. Anne I. Boyd, Washington, D. C., yellow-shouldered parrot.

Messrs. L. A. Branchaud, Havre de Grace, Md., and H. C. Oberholser, through United States Biological Survey, whistling swan.

Mr. John S. Burrows, Washington, D. C., white-throated capuchin.

Mrs. C. J. Caithness, Washington, D. C., grass paroquet.

Mr. F. G. Carnochan, New York City, white-thighed colobus, chimpanzee.

Mr. W. Chavous, Washington, D. C., black snake.

Mr. Charles M. Clark, Washington, D. C., canary.

Mr. Walter P. Chrysler, Detroit, Mich., saddle-bill stork, 2 viscachas, bell bird.

Mr. and Mrs. Campbell Church, jr., Seattle, Wash., 2 Sitka bears.

Mrs. D. M. Cole, Beloit, Wis., 3 flying squirrels.

Miss Jean Craighead, Chevy Chase, Md., turkey vulture.

Miss Mary Daly, Washington, D. C., gray fox.

Mr. A. H. Davis, Palmyra, Va., Cuban parrot.

Mr. Talbot Denmead, Washington, D. C., call duck.

Mrs. E. N. Dingley, Washington, D. C., red fox.

Mr. J. H. Dobbins, Washington, D. C., 2 woodchucks.

Mrs. Mary Dowling, Washington, D. C., sparrow hawk.

Major Albert F. Drake, Ashton, Md., goat.

Mrs. Herbert Elmore, Washington, D. C., coyote.

Mr. E. T. Evans, through United States Department of Agriculture, soft-shell turtle.

Miss Harriet A. Fellows, Washington, D. C., 2 painted turtles.

Franklin Park Zoo, Boston, Mass., water snake, boa.

M. de Freygang, Usambura, Urundi, Africa (through F. G. Carnochan) Killimbira guenon.

Mr. A. L. Goolsbe, Washington, D. C., white-throated capuchin.

Mr. W. A. Graves, Richmond, Va., raccoon.

Mr. Walter Greene, Washington, D. C., titi monkey.

Gude Bros., Washington, D. C., 3 alligators.

Mr. O. Hallson, through Alaska Game Commission and United States Biological Survey, Bethel, Alaska, 6 Emperor geese.

Mr. Rodney Hart, Washington, D. C., flying squirrel.

Mr. R. Hartshorn, Washington, D. C., copperhead.

Mr. Stephen Haweis, Dominica, British West Indies, 4 giant toads, 7 Dominican frogs.

Mr. C. L. Head, Washington, D. C., 2 canaries.

Mr. Rush L. Holland, Washington, D. C., yellow-fronted parrot.

Mrs. Mary Hosick, Washington, D. C., double yellow-headed parrot.

Mr. Philip R. Hough, East Falls Church, Va., 4 box turtles, wood tortoise, common snapping turtle.

Mr. A. B. Howell, Baltimore, Md., Emperor boa.

Mr. J. A. Hyslop, jr., Silver Spring, Md., 2 copperheads, fence lizard, blue racer, black snake, 2 hog-nosed snakes.

Dr. H. H. T. Jackson, United States Biological Survey, 3 musk turtles, 10 ornate turtles.

Capt. John N. Johnson, Fort George G. Meade, Md., hog-nosed snake.

Mr. E. R. Kalmbach, United States Biological Survey, 3 California gulls, 7 ring-billed gulls, 5 caspian terns, 5 shovellers, 7 coots, 7 green-winged teals.

Dr. H. C. Kellers, United States Navy, 7 regal pythons, 2 Philippine water dragons, 4 Philippine monitors, 3 Philippine macaques, common jungle fowl, Malay Brahminy kite, 13 tangalunga and Philippine palm-civets, 12 bleeding-heart doves, 16 green-winged doves.

Mr. M. A. Kendall, Holtville, Calif., 2 tricolor ground snakes.

Mr. Jack Knauer, Washington, D. C., 11 opossums.

Mr. E. H. Kreh, Frederick, Md., copperhead.

Mr. Samuel Kress, through the United Fruit Co., Costa Rican deer, collared peccary, imperial boa.

Mr. C. D. Langdon, Washington, D. C., raccoon.

Mrs. F. S. Long, Washington, D. C., Cuban parrot.

Mr. John L. Magnus, Washington, D. C., ring-necked pheasant.

Mrs. McCormick-Goodhart, Hyattsville, Md., 2 cockatiels.

Mr. E. B. McLean, Friendship, D. C., 2 black mallards, call duck.

Mr. R. F. McMahon, Washington, D. C., 2 barn owls.

Mr. Bob McPherson, Johnny Jones Carnival, murine opossum.

Mr. F. Miller, Washington, D. C., garter snake.

Mr. Walter L. Mitchell, East Falls Church, Va., black Carolina vulture.

Mr. O. J. Murie, Jackson, Wyo., through United States Biological Survey, 7 Rocky Mountain jays, long crested jay.

Mr. M. E. Musgrave, Phoenix, Ariz., through United States Biological Survey, red racer.

Mr. Wilfred Nerlich, Washington, D. C., ferret.

Mr. E. S. Newman, Washington, D. C., ring-necked pheasant.

Mr. Harry Norment, Washington, D. C., double yellow-headed parrot.

Dr. A. Obele, Washington, D. C., 2 alligators.

Miss Frances Owen, Chevy Chase, D. C., 2 screech owls.

Mr. R. G. Paine, Washington, D. C., black snake.

Mrs. P. B. Parke, Chevy Chase, Md., 2 goldfinches.

Mr. W. M. Perrygo, National Museum, 6 green vine snakes, 3 Haitian boas, 2 garter snakes, 2 turtles, 6 rhinoceros iguanas, West Indian crocodile, West Indian tree duck, bobwhite, white-winged dove, West Indian dove, ground dove, red-shouldered hawk.

Mr. W. B. Pierce, Washington, D. C., alligator.

Hon. Gifford Pinchot, Washington, D. C., Duncan Island tortoise, Hood Island tortoise, 3 Galapagos iguanas, 4 Albemarle tortoises.

Mr. Lincoln Potter, Washington, D. C., 2 turkey vultures.

Mr. and Mrs. S. H. Rathbun, Washington, D. C., yellow and blue macaw.

Mrs. Mary Roberts Rinehart, Washington, D. C., white-throated capuchin.

Mr. W. H. Rogers, Liverpool, England, 2 New Guinea brown pigeons.

Messrs. Theodore Roosevelt, jr., Harold S. Coolidge, jr., and Ralph Wheeler (Kelly-Roosevelt expedition), 3 white-cheeked gibbons, 2 pig-tailed monkeys, 3 rhesus monkeys, sun bear, Himalayan bear, Bay bamboo rat.

Mr. C. M. Rose, Wheeling, W. V., yellow-shouldered parrot.

Mr. Walter Deane Rose, Washington, D. C., 3 horned lizards.

Mr. H. H. Rudolph, Washington, D. C., 2 ring-necked pheasants.

San Diego Zoological Society, San Diego, Calif., 2 rat kangaroos.

Mr. Helmar C. Schmidt, Eastport, Md., American crow.

Mr. A. P. Scott, Isle of Wight Co., Va., bald eagle.

Mr. P. E. Siggers, Washington, D. C., 100 white mice.

Mr. H. H. Shamel, Washington, D. C., woodchuck, 2 muskrats.

Mr. Raymond C. Shannon, National Museum, Washington, D. C., douroucouli, squirrel monkey, yaguarundi.

Mr. Robert Shosteck, Washington, D. C., pine skink.

Mr. P. W. Shufeldt, Belize, British Honduras, Baird's tapir.

Mr. G. T. Smallwood, Chevy Chase, D. C., Marine turtle.

Mr. Donald Smith, Chevy Chase, Md., common snapping turtle.

Commander Kirby Smith, United States Navy, 2 green-rumped parrotlets, Venezuelan parrot, 2 blue-winged paroquets.

Mrs. J. L. Stafford, Washington, D. C., Cuban parrot.

Mrs. M. Stallsmith, Kensington, Md., orange-fronted parrot.

Mr. F. W. Steele, Charleston, W. Va., 6 opossums.

Mr. Clifton Stone, Washington, D. C., 4 horned lizards.

Mr. W. R. Tayloe, Fredericksburg, Va., plains wolf.

Mr. Oliver Taylor, Washington, D. C., 2 alligators.

Dr. J. P. Thomas, Miami, Fla., Philippine macaque.

Misses Helen and Emily Thour, Washington, D. C., 2 alligators.

Mrs. Tolson, Washington, D. C., yellow-fronted parrot.

Mr. F. M. Uhler, through United States Biological Survey, weasel.

Mrs. Walsh, Washington, D. C., opossum.

Mrs. Martha I. Weaver, Washington, D. C., African gray parrot.

Mrs. Charles M. Weeks, Chevy Chase, Md., white-throated capuchin.

Mr. G. T. Wells, Gaithersburg, Md., barn owl.

Mrs. Wm. Werntz, Annapolis, Md., orange-crowned parrot.

Mrs. Whitehorne, Washington, D. C., cedar wax-wing.

Mr. C. E. Whittington, United States Department of Agriculture, chicken turtle.

Mr. Orme Wilson, Washington, D. C., capuchin.

Mrs. Works, Washington, D. C., grass parrakeet.

Mrs. George M. Wright, Washington, D. C., double yellow-headed parrot.

Births.—There were 56 mammals born and 5 birds hatched in the Park during the year. These include the following:

*Mammals*

| Scientific name | Common name | Number |
|---|---|---|
| Ammotragus lervia | Aoudad | 1 |
| Axis axis | Axis deer | 1 |
| Bison bison | American bison | 1 |
| Bubalus bubalis | Indian buffalo | 1 |
| Canis latrans | Coyote | 2 |
| Canis nubilus | Plains wolf | 5 |
| Cervus duvauceiii | Barasingha deer | 1 |
| Cervus elaphus | Red deer | 1 |
| Dama dama | Fallow deer | 3 |
| Equus przewalskii | Mongolian wild horse | 1 |
| Felis leo | Lion | 2 |
| Genetta dongalana neumanni | Neumann's genet | 2 |
| Glaucomys volans | Flying squirrel | 4 |
| Hippopotamus amphibius | Hippopotamus | 1 |
| Lama glama | Llama | 2 |
| Macaca fuscata | Japanese monkey | 1 |
| Nasua narica | Coatimundi | 3 |
| Odocoileus costaricensis | Costa Rican deer | 1 |
| Ovis canadensis | Rocky Mountain sheep | 4 |
| Ovis europaeus | Mouflon | 1 |
| Phacochoerus aethiopicus | Wart hog | 4 |
| Poephagus grunniens | Yak | 2 |
| Procyon lotor | Raccoon | 9 |
| Sika nippon | Japanese deer | 3 |

*Birds*

| Scientific name | Common name | Number |
|---|---|---|
| Branta canadensis occidentalis | White-cheeked goose | 3 |
| Pellecanus erythrorhynchos | American white pelican | 2 |

*Purchases and exchanges.*—Among the most important purchases during the year were a pair of maccaroni penguins, four pairs of birds of paradise (Wilson's, Magnificent, King, and 12-wired), a golden headed mynah, a pair of spectacled owls, and a pair of European eagle owls, the last two being from the estate of Spedan Lewis, the noted English aviculturist; and an imperial parrot secured in Dominica through Mr. Stephan Haweis.

A pigmy hippopotamus was bought as a mate to the one already in the collection, and a male Molucca deer was also bought for the same purpose. The zoo purchased a pair of sea lions to replace those that died last year; a pair of jaguars, which have been lacking in our collection; and a black jaguar. The last is the third of its kind to come to the United States, and is an exceedingly rare and beautiful specimen.

Important animals received in exchange during the year were a pair of Molucca deer, and two pairs of axis deer, three keas, and a rare wallaroo.

REMOVALS

The most serious loss to the collection was that of old Mom, the female hippopotamus, who had been at the Park for 19 years, and during that time had given birth to seven young, five of which were raised.

*Causes of death.*—When it has been thought that determination of the cause of death of certain animals might be useful, the specimens have been submitted to the Pathological Division of the Bureau of Animal Industry for examination. The following list shows the results of the autopsies:

MAMMALS

Carnivora: Hemorrhagic septicemia, 1; chronic pneumonia, 1.
Pinnipedia: Gastritis, 1.
Primates: Intestinal parasites, 1.
Ungulata: Gastroenteritis, 3; pneumonia, 1; internal hemorrhage, 1; bilateral hemorrhagic impact of the adrenals, 1; no cause found, 1.
Rodentia: No cause found, 1.

BIRDS

Anseriformes: Enteritis, 2; no cause found, 1.
Gruiformes: No cause found, 1.
Psittaciformes: Tuberculosis, 1.
Passeriformes: Enteritis, 1; no cause found, 1.

REPTILES

Chelonia: Intestinal ulceration, 1.

## ANIMALS IN THE COLLECTION JUNE 30, 1930

*Mammals*

| Scientific name | Common name | Number |
|---|---|---|
| MARSUPIALIA | | |
| Caloprymnus campestris | Rat kangaroo | 2 |
| Didelphis virginiana | Opossum | 21 |
| Macropus robustus | Wallaroo or Euro | 1 |
| Macropus rufus | Great red kangaroo | 1 |
| Phascolomys mitchelli | Wombat | 1 |
| CARNIVORA | | |
| Acinonyx jubatus | Cheeta | 1 |
| Arctictis binturong | Binturong or "Bear-Cat" | 1 |
| Bassariscus astutus | Cacomixle or ring-tail | 1 |
| Canis dingo | Dingo | 1 |
| Canis latrans | Coyote | 8 |
| Canis latrans | Albino coyote | 1 |
| Canis mesomelas | Black-backed jackal | 1 |
| Canis nubilus | Plains wolf | 11 |
| Crocuta crocuta germinans | East African spotted hyena | 1 |
| Felis capensis hindei | East African serval | 2 |
| Felis caracal nubica | Abyssinian lynx | 1 |
| Felis concolor azteca | Mexican puma | 3 |
| Felis leo | Lion | 8 |
| Felis onca | Jaguar | 2 |
| Felis onca | Black jaguar | 1 |
| Felis pardalis brasiliensis | Brazilian ocelot | 1 |
| Felis pardalis griffithii | Ocelot | 1 |
| Felis pardalis var | Ocelot | 1 |
| Felis pardus | Leopard, African | 5 |
| Felis serval | Serval | 1 |
| Felis tigris | Bengal tiger | 1 |
| Felis tigris longipilis | Manchurian tiger | 1 |
| Gennetta dongalana neumanni | Neumann's genet | 4 |
| Gulo luscus | Wolverine | 2 |
| Helarctos malayanus | Sun bear | 2 |
| Herpestes ichneumon | Egyptian mongoose | 1 |
| Hyaena brunnea | Brown hyena | 2 |
| Lutra canadensis vaga | Florida otter | 1 |
| Lynx baileyi | Bailey's lynx | 1 |
| Lynx caracal | Caracal | 1 |
| Lynx rufus | Bay lynx | 2 |
| Mellivora capensis | Ratel | 1 |
| Mephitis nigra | Skunk | 3 |
| Mustela furo | Ferret | 1 |
| Mustela noveboracensis | Weasel | 1 |
| Nasua sp | Coatimundi, silky-brown | 1 |
| Nasua sp | Coatimundi, dark brown | 1 |
| Nasua narica | Coatimundi, gray | 5 |
| Paradoxurus philippensis | Philippine palm-civet | 7 |
| Potos flavus | Kinkajou | 6 |
| Procyon cancrivorus | Crab-eating raccoon | 2 |
| Procyon lotor | Raccoon | 19 |
| Proteles cristatus | Aard-wolf | 1 |
| Taxidea taxus | American badger | 2 |
| Tayra barbara | Tayra | 1 |
| Thalarctos maritimus | Polar bear | 3 |
| Urocyon cinereoargenteus | Gray fox | 4 |
| Ursus americanus | Black bear | 5 |
| Ursus americanus cinnamoneus | Cinnamon bear | 2 |
| Ursus apache | Apache grizzly | 1 |
| Ursus arctos | European brown bear | 7 |
| Ursus emmonsii | Glacier bear | 1 |
| Ursus gyas | Alaska Peninsula brown bear | 4 |
| Ursus horribilis | Grizzly bear | 1 |

*Mammals*—Continued

| Scientific name | Common name | Number |
|---|---|---|
| CARNIVORA—continued | | |
| Ursus kidderi | Kidder's bear | 2 |
| Ursus middendorffi | Kodiak bear | 2 |
| Ursus sitkensis | Sitka bear | 2 |
| Ursus thibetanus | Himalayan bear | 2 |
| Viverra civetta | Civet | 1 |
| Viverra tangalunga | Tangalunga | 1 |
| Vulpes fulva | Red fox | 7 |
| Vulpes fulva | Silver-black fox | 1 |
| Vulpes velox | Kit fox | 1 |
| PINNIPEDIA | | |
| Callorhinus alascanus | Northern fur seal | 2 |
| Phoca richardii | Pacific harbor seal | 2 |
| Phoca richardii geronimensis | San Geronimo harbor seal | 1 |
| Zalophus californianus | California sea lion | 2 |
| PRIMATES | | |
| Aotus trivirgatus | Douroucouli | 1 |
| Ateles geoffroyi | Gray spider monkey | 3 |
| Cebus capucinus | Grizzled capuchin | 4 |
| Cebus hypoleucus | White-throated capuchin | 7 |
| Cercocebus fuliginosus | Sooty mangabey | 4 |
| Cercopithecus albigularis | Sykes' or "blue" monkey | 5 |
| Cercopithecus brazzae | DeBrazza's guenon | 1 |
| Cercopithecus callitrichus | Green guenon | 2 |
| Cercopithecus diana | Diana monkey | 1 |
| Cercopithecus griseoviridis | Grivet monkey | 2 |
| Cercopithecus l'hoesti | Killimbira guenon | 1 |
| Cercopithecus labiata | Samango guenon | 1 |
| Cercopithecus mona | Mona monkey | 3 |
| Cercopithecus pygerythra | Vervet | 1 |
| Cercopithica petaurista | Lesser white-nosed guenon | 2 |
| Colobus vellerosus | White-thighed colobus | 1 |
| Cynopithecus sp | Ape | 1 |
| Gorilla gorilla | Gorilla | 1 |
| Hylobates leucogenys | White-cheeked gibbon | 3 |
| Lemur macaco | Black lemur | 1 |
| Lemur rufifrons | Red-fronted lemur | 1 |
| Macaca andamanensis | Burmese macaque | 1 |
| Macaca fuscata | Japanese monkey | 4 |
| Macaca irus | Crab-eating macaque | 1 |
| Macaca mordax | Javan macaque | 4 |
| Macaca nemestrina | Pig-tailed monkey | 1 |
| Macaca rhesus | Bengal or rhesus monkey | 7 |
| Macaca speciosus | Red-faced monkey | 1 |
| Macaca syrichta | Philippine monkey | 3 |
| Magus maurus | Moor monkey | 2 |
| Pan satyrus | Chimpanzee | 2 |
| Papio cynocephalus | Anubis or yellow baboon | 2 |
| Papio hamadryas | Hamadryas baboon | 1 |
| Papio leucophaeus | Drill | 1 |
| Papio neumanii | Olive baboon | 2 |
| Papio porcarius | Chacma | 2 |
| Papio sphinx | Mandrill | 3 |
| Saimiri sciureus | Titi monkey or squirrel monkey | 2 |
| Simia sylvanus | Barbary ape | 2 |
| RODENTIA | | |
| Mus sp | White mice | 100 |
| Acanthion brachyurum | Malay porcupine | 2 |
| Castor canadensis | American beaver | 2 |
| Cavia porcellus | Domestic guinea pig | 30 |
| Citellus tridecemlineatus | 13-striped gopher | 6 |
| Cuniculus paca virgatus | Central American paca | 3 |
| Cynomys ludovicianus | Prairie dogs | 12 |
| Dasyprocta punctata | Speckled agouti | 2 |
| Dasyprocta rubrata | Trinidad agouti | 6 |
| Dolichotis patagonica | Patagonian cavy | 2 |
| Glaucomys volans | Flying squirrel | 9 |
| Hydrochoerus hydrochaeris | Capybara | 1 |
| Hystrix africaeaustralis | African porcupine | 3 |
| Lagostomus trichodactylus | Viscacha | 2 |
| Marmota monax | Woodchuck | 8 |
| Ondatra zibethica | Muskrat | 2 |
| Rhizomys badius | Bay Bamboo rat | 1 |
| Sciurus carolinensis | Albino squirrel | 2 |
| Sciurus niger | Fox squirrel | 1 |

*Mammals*—Continued

| Scientific name | Common name | Number |
|---|---|---|
| LAGOMORPHA | | |
| Oryctolagus cuniculus | Domestic rabbit | 2 |
| ARTIODACTYLA | | |
| Æpyceros melampus suara | East African impalla | 2 |
| Ammotragus lervia | Aoudad | 4 |
| Anoa depressicornis | Anoa | 1 |
| Antilope cervicapra | Black buck or Indian antelope | 1 |
| Axis axis | Axis deer | 4 |
| Bison bison | American bison | 14 |
| Bos indicus | Zebu | 1 |
| Boselaphus tragocamelus | Nilgai | 2 |
| Camelus bactrianus | Bactrian camel | 1 |
| Camelus dromedarius | Arabian camel | 1 |
| Bubalus bubalis | Indian buffalo | 2 |
| Capra hircus | Goat | 4 |
| Capra ibex | Alpine ibex | 2 |
| Cervus canadensis | American elk or wapiti | 4 |
| Cervus duvaucelii | Barasingha deer | 7 |
| Cervus elaphus | Red deer | 12 |
| Cervus hanglu | Kashmir deer | 2 |
| Cervus xanthopygus | Bedford deer | 5 |
| Connochaetes taurinus | Brindled gnu | 1 |
| Connochaetes taurinus albojubatus | White-bearded gnu | 2 |
| Dama dama | Fallow deer (white) | 2 |
| Dama dama | Fallow deer | 11 |
| Hemitragus jemlahicus | Tahr | 5 |
| Hyelaphus porcinus | Hog deer | 3 |
| Lama glama | Llama | 9 |
| Lama huanacus | Guanaco | 2 |
| Odocoileus costaricensis | Costa Rican deer | 2 |
| Odocoileus hemionus | Mule deer | 2 |
| Odocoileus sitkensis | Sitka black-tail deer | 2 |
| Odocoileus virginianus | Virginia deer | 3 |
| Oreamnos americanus | Mountain goat | 2 |
| Ovibos moschatus wardi | Greenland musk-ox | 3 |
| Ovis canadensis | Rocky Mountain sheep | 10 |
| Ovis europaeus | Mouflon | 6 |
| Pecari angulatus | Peccary | 4 |
| Phacochoerus aethiopicus | Wart hog | 5 |
| Poephagus grunniens | Yak | 8 |
| Potamochoerus africanus | Bush pig | 1 |
| Rangifer tarandus | Reindeer | 4 |
| Rucervus eldii | Burmese deer | 1 |
| Rusa moluccensis | Molucca deer | 2 |
| Sika nippon | Japanese deer | 10 |
| Strepsiceros strepsiceros | Greater kudu | 1 |
| Sus scrofa | European wild boar | 2 |
| Synceros caffer | South African buffalo | 1 |
| Tragelaphus angasi | Inyala | 1 |
| Tragelaphus scriptus | Harnessed antelope | 2 |
| PERISSODACTYLA | | |
| Choeropsis liberiensis | Pigmy hippopotamus | 2 |
| Equus grevyi-asinus | Zebra-ass hybrid | 2 |
| Equus grevyi-caballus | Zebra-horse hybrid | 1 |
| Equus onager | Kiang or wild ass | 1 |
| Equus przewalskii | Mongolian wild horse | 3 |
| Equus quagga chapmani | Chapman's zebra | 2 |
| Equus zebra | Mountain zebra | 2 |
| Hippopotamus amphibius | Hippopotamus | 1 |
| Tapirella bairdii | Baird's tapir | 1 |
| Tapirus terrestris | Brazilian tapir | 1 |
| PROBOSCIDEA | | |
| Elaphas sumatranus | Sumatra elephant | 1 |
| Loxodonta africana oxyotis | African elephant | 1 |
| EDENTATA | | |
| Dasypus novemcinctus | 9-banded armadillo | 1 |

*Birds*

| Scientific name | Common name | Number |
|---|---|---|
| RATITAE | | |
| Casuarius philipi | Sclater's cassowary | 1 |
| Casuarius unipendiculatus | Cassowary, single-wattled | 2 |
| Dromiceius novae hollandiae | Common emu | 3 |
| Rhea americana | Common rhea or nandu | 1 |
| Struthio australis | South African ostrich | 3 |
| Struthio camelus | Nubian ostrich | 1 |
| Struthio molybdophanes | Somali ostrich | 1 |
| SPHENISCIFORMES | | |
| Eudyptes chrysolophus | Maccaroni penguin | 1 |
| PELECANIFORMES | | |
| Anhinga anhinga | Anhinga or snake bird | 1 |
| Pelecanus californicus | California brown pelican | 4 |
| Pelecanus conspicillatus | Australian pelican | 2 |
| Pelecanus erythrorhynchos | American white pelican | 8 |
| Pelecanus occidentalis | Brown pelican | 5 |
| Pelecanus onocrotalus | European white pelican | 2 |
| Pelecanus roseus | Rose-colored pelican | 1 |
| Phalacrocorax auritus floridanus | Florida cormorant | 1 |
| CICONIIFORMES | | |
| Ajaja ajaja | Roseate spoonbill | 2 |
| Ardea goliath | Goliath heron | 2 |
| Ardea herodias | Great blue heron | 2 |
| Ardea occidentalis | Great white heron | 2 |
| Balaeniceps rex | Shoe-bill stork | 1 |
| Cochlearius cochlearius | Boat-billed heron | 3 |
| Ephippiorhynchus senegalensis | Saddle-billed stork | 1 |
| Guara alba | White ibis | 4 |
| Guara rubra | Scarlet ibis | 3 |
| Leptoptilus dubius | Indian adjutant | 2 |
| Leptoptilus javanicus | Lesser adjutant | 2 |
| Mycteria americana | Wood ibis | 1 |
| Nycticorax nycticorax naevius | Black-crowned night heron | 55 |
| Threskiornis aethiopicus | Sacred ibis | 2 |
| Threskiornis melanocephalus | Black-headed ibis | 2 |
| ANSERIFORMES | | |
| Aix sponsa | Wood duck | 2 |
| Alopochen aegyptiacus | Egyptian goose | 1 |
| Alopochen jubatus | Orinoco goose | 1 |
| Anas platyrhynchos | Call duck | 1 |
| Anas platyrhynchos | Mallard | 36 |
| Anas rubripes | Black or dusky mallard | 1 |
| Anas undulata | African yellow-billed duck | 2 |
| Anser albifrons | White-fronted goose | 5 |
| Anser brachyrhynchus | Pink-footed goose | 1 |
| Anser cinereus domestica | Toulouse goose | 2 |
| Anser fabalis | Bean goose | 2 |
| Branta bernicla glaucogastra | Brant | 7 |
| Branta canadensis canadensis | Canada goose | 13 |
| Branta canadensis hutchinsii | Hutchins goose | 2 |
| Branta canadensis minima | Cackling goose | 2 |
| Branta canadensis occidentalis | White-cheeked goose | 19 |
| Branta leucopsis | Barnacle goose | 2 |
| Cairina moschata | Muscovy duck | 2 |
| Casarca variegata | Paradise duck | 2 |
| Chaulelasmus streperus | Gadwall | 2 |
| Chen caerulescens | Blue goose | 9 |
| Chenopis atrata | Black swan | 5 |
| Cygnopsis cygnoides | Chinese goose | 1 |
| Cygnus gibbus | Mute swan | 1 |
| Dafila acuta | Pintail | 2 |
| Dafila bahamensis | Bahama pintail | 3 |
| Dendrocygna arborea | West Indian tree duck | 1 |
| Dendrocygna autumnalis | Black-bellied tree duck | 1 |
| Dendrocygna eytoni | Eyton's tree duck | 3 |
| Eulabeia indica | Bar-headed goose | 2 |
| Mareca americana | Baldpate | 3 |
| Metopiana peposaca | Rosy-billed pochard | 3 |
| Nesochen sandvicensis | Hawaiian goose | 1 |
| Nettion carolinense | Green-winged teal | 2 |
| Nettion formosum | Baikal teal | 1 |
| Nyroca americana | Redhead | 4 |
| Nyroca valisineria | Canvas-back | 3 |

*Birds*—Continued

| Scientific name | Common name | Number |
|---|---|---|
| ANSERIFORMES—continued | | |
| Olor columbianus | Whistling swan | 2 |
| Philacte canagica | Emperor goose | 3 |
| Plectropterus gambensis | Spur-winged goose | 4 |
| Querquedula querquedula | Garganey | 2 |
| FALCONIFORMES | | |
| Aegypius monachus | Cinerous vulture | 2 |
| Aquila chrysaetos | Gold eagle | 4 |
| Aquila rapax | Tawny eagle | 2 |
| Buteo borealis | Red-tailed hawk | 3 |
| Buteo lineatus | Red-shouldered hawk | 1 |
| Buteo platypterus | Broad-winged hawk | 4 |
| Cathartes aura | Turkey vulture | 4 |
| Coragyps atratus | Black vulture | 2 |
| Elanus caeruleus | White kite | 1 |
| Falco peregrinus | Peregrine falcon | 1 |
| Falco sparverius | Sparrow hawk | 3 |
| Gymnogyps californianus | California condor | 3 |
| Gyps rueppelli | Ruppell's vulture | 2 |
| Haliaeetus leucocephalus | Bald eagle | 16 |
| Haliastur indus | Malay brahminy kite | 1 |
| Milvus migrans | Yellow-billed kite | 1 |
| Otogyps auricularis | African eared vulture | 3 |
| Polyborus cheriway | Audubon's caracara | 4 |
| Pseudogyps africanus | White-headed vulture | 1 |
| Sagittarius serpentarius | Secretary vulture | 1 |
| Sarcoramphus papa | King vulture | 2 |
| Torgos tracheliotus | African black vulture | 1 |
| Uroaetus audax | Wedge-tailed eagle | 2 |
| Vultur gryphus | South American condor | 1 |
| GALLIFORMES | | |
| Acryllium vulturinum | Vulturine guinea-fowl | 3 |
| Argusianus argus | Argus pheasant | 2 |
| Colinus virginianus | Bob-white | 1 |
| Chrysolophus amherstiae | Lady Amherst's pheasant | 1 |
| Chrysolophus pictus x amherstiae | Hybrid pheasant | 1 |
| Coturnix coturnix | Migratory quail | 4 |
| Crax globicera | Mexican curassow | 2 |
| Crax globulosa | Spix's wattled curassow | 3 |
| Crax panamensis | Panama curassow | 1 |
| Excalfactoria chinensis | Pigmy quail | 3 |
| Gallus varius | Javan jungle fowl | 1 |
| Gennaeus edwardsi | Edwards's pheasant | 1 |
| Gennaeus nycthemerus | Silver pheasant | 2 |
| Lophortyx californica vallicola | Valley quail | 1 |
| Mitu mitu | Razor-billed curassow | 1 |
| Numida mitrata reichenowi | Reichenow's helmeted guinea-fowl | 5 |
| Oreortyx picta | Montain quail | 1 |
| Ortalis cinereiceps | Gray-headed chachalaca | 2 |
| Ortalis leucogastra | Chachalaca | 1 |
| Pavo cristatus | Peafowl | 10 |
| Pavo cristatus | White peafowl | 2 |
| Penelope boliviana | Crested guan | 2 |
| Phasianus torquatus | Ring-necked pheasant | 17 |
| GRUIFORMES | | |
| Anthropoides virgo | Demoiselle crane | 3 |
| Balearica pavonina | West African crowned crane | 5 |
| Dissura episcopus | Woolly-necked stork | 1 |
| Fulica americana | Coot | 8 |
| Gallinula chloropus brachyptera | African moorhen | 2 |
| Gallirallus australis | South Island weka rail | 1 |
| Grus canadensis | Little brown crane | 3 |
| Grus leucauchen | White-naped crane | 1 |
| Grus leucogeranus | Siberian crane | 1 |
| Grus lilfordi | Lilford's crane | 1 |
| Grus mexicana | Sandhill crane | 2 |
| Grus nigricollis | Manchurian crane | 2 |
| Hypotaenidia philippensis | Lesser rail | 2 |
| Mathewsena rubicunda | Australian crane | 2 |
| Microtribonyx ventralis | Black-tailed moorhen | 1 |
| Porphyrio melanotus | New Zealand mudhen | 1 |
| Psophia crepitans | Trumpeter | 2 |
| Psophia viridis | Green-winged trumpeter | 1 |
| Rhynochetos jubatus | Kagu | 1 |
| Tetrapteryx paradisea | Stanley or paradise crane | 2 |

*Birds*—Continued

| Scientific name | Common name | Number |
|---|---|---|
| CHARADRIIFORMES | | |
| Larus argentatus | Herring gull | 2 |
| Larus atricilla | Laughing gull | 1 |
| Larus californicus | California gull | 10 |
| Larus marinus | Great black-backed gull | 2 |
| Larus novaehollandiae | Silver gull | 34 |
| Larus occidentalis | Western gull | 6 |
| Oedicnemus bistriatus vocifer | South American stone plover | 1 |
| Philomachus pugnax | Ruff | 5 |
| Sterna caspia | Caspian tern | 5 |
| COLUMBIFORMES | | |
| Caloenas nicobarica | Nicobar pigeon | 5 |
| Chalcophaps indica | Green-winged dove | 3 |
| Columba guinea | Speckled pigeon | 4 |
| Gallicolumba luzonica | Bleeding-heart dove | 4 |
| Globicera pacifica | Pacific pigeon | 1 |
| Goura victoria | Victoria crowned pigeon | 1 |
| Janthoenas vitiensis | White-throated fruit pigeon | 1 |
| Macropygia doreya | New Guinea brown pigeon | 1 |
| Melopelia asiatica | White-winged dove | 1 |
| Oena capensis | Namaqua dove | 1 |
| Streptopelia risoria | Ringed turtledove | 1 |
| Streptopelia senegalensis | East African ring-necked dove | 17 |
| Streptopelia sp | Ground dove | 1 |
| Turtur chalcospilos | Emerald-spotted ground dove | 1 |
| Zenaidura macroura carolinensis | Mourning dove | 1 |
| Zenaidura macroura macroura | West Indian dove | 1 |
| CUCULIFORMES | | |
| Eudynamis honorata | Indian koel | 1 |
| Turacus leucotis donaldsoni | Donaldson's turacou | 1 |
| PSITTACIFORMES | | |
| Agapornis fischeri | Fischer's love-bird | 2 |
| Agapornis lilianae | Nyassa love-bird | 9 |
| Agapornis madagascariensis | Gray-headed love-bird | 3 |
| Agapornis personata | Yellow-collared love-bird | 1 |
| Agapornis pullaria | Red-faced love-bird | 2 |
| Agapornis taranta | Abyssinian love-bird | 3 |
| Amazona sp | ——— parrot | 1 |
| Amazona aestiva | Amazona parrot | 1 |
| Amazona albifrons | White-fronted parrot | 9 |
| Amazona albifrons nana | Lesser white-fronted parrot | 1 |
| Amazona amazonica | Orange-winged parrot | 3 |
| Amazona arausiaca | Bouquet's parrot | 1 |
| Amazona auropalliata | Yellow-naped parrot | 2 |
| Amazona farinosa | Mealy parrot | 1 |
| Amazona festiva | Festive parrot | 2 |
| Amazona leucocephala | Cuban parrot | 6 |
| Amazona ochrocephala | Yellow-fronted parrot | 8 |
| Amazona ochroptera | Yellow-shouldered parrot | 2 |
| Amazona oratrix | Double-yellow-head parrot | 9 |
| Amazona ventralis | Santo Domingo parrot | 1 |
| Amazona viridigenalis | Red-crowned parrot | 5 |
| Anodorhynchos hyacinthinus | Hyacinthine macaw | 1 |
| Aprosmictus erythropterus | Crimson-winged paroquet | 1 |
| Ara ararauna | Yellow and blue macaw | 5 |
| Ara macao | Red, blue and yellow macaw | 3 |
| Ara maracana | Illiger's macaw | 1 |
| Ara mexicana | Mexican green macaw | 2 |
| Ara sp | Macaw | 1 |
| Aratinga rubritorquis | Red-throated conure | 1 |
| Brotogeris jugularis | Tovi paroquet | 2 |
| Brotogeris virescens | White-winged paroquet | 1 |
| Conurus longicauda | Long-tailed paroquet | 2 |
| Conurus nepalensis | Nepalese paroquet | 1 |
| Coracopsis nigra | Lesser vasa parrot | 1 |
| Coracopsis vasa | Greater vasa parrot | 1 |
| Cyanopsittacus spixi | Spix's macaw | 2 |
| Deroptyus accipitrinus | Hawk-head parrot | 2 |
| Eos bornea | Red lory | 2 |
| Eos variegata | Purple lory | 1 |
| Eupsittula aurea | Golden-crowned paroquet | 2 |
| Eupsittula canicularis | Petz' paroquet | 2 |
| Eupsittula jendaya | Jenday paroquet | 1 |
| Eupsittula weddellii | Weddell's paroquet | 3 |
| Kakatoe alba | White cockatoo | 1 |
| Kakatoe galerita | Sulphur-crested cockatoo | 3 |

*Birds*—Continued

| Scientific name | Common name | Number |
|---|---|---|
| PSITTACIFORMES—continued | | |
| Kakatoe gymnopis | Bare-eyed cockatoo | 1 |
| Kakatoe leadbeateri | Leadbeater's cockatoo | 2 |
| Kakatoe moluccensis | Great red-crested cockatoo | 1 |
| Kakatoe roseicapilla | Roseate cockatoo | 11 |
| Leptolophus novae-hollandicus | Cockatiel | 2 |
| Lorius domicella | Ceram lory | 1 |
| Melopsittacus undulatus | Grass paraquet | 8 |
| Microglossus aterrimus | Great black cockatoo | 1 |
| Myiopsitta monachus | Quaker paroquet | 3 |
| Nandayus nanday | Nanday paroquet | 1 |
| Nestor notabilis | Kea | 6 |
| Pionus maximiliani | Maximilian's parrot | 1 |
| Pionus menstruus | Blue-headed parrot | 2 |
| Pionites xanthomeria | Amazonian caique | 3 |
| Platycercus eximius | Rosella paroquet | 1 |
| Poicephalus meyeri matschiei | East African brown parrot | 2 |
| Psephotus haematorrhous | Red-vented blue-bonnet paroquet | 1 |
| Psittacus erithacus | African gray parrot | 1 |
| Psittaculus guianensis | Green-rumped parrotlet | 2 |
| Pyrrhura picta | Blue-winged conure | 1 |
| Tanygnathus megalorhynchus | Great-billed paroquet | 1 |
| Trichoglossus cyanogrammus | Green-naped lorikeet | 1 |
| Trichoglossus forsteni | Forsten's paroquet | 3 |
| Trichoglossus ornatus | Ornate lory | 1 |
| STRIGIFORMES | | |
| Bubo africanus | Spotted eagle-owl | 1 |
| Bubo bubo | Eagle-owl | 3 |
| Bubo virginianus | Great horned owl | 5 |
| Bubo virginianus | Great horned owl (albino) | 1 |
| Nyctea nyctea | Snowy owl | 1 |
| Otus asio | Screech owl | 4 |
| Pulsatrix perspicillata | Spectacled owl | 1 |
| Strix varia varia | Barred owl | 4 |
| Tyto alba affinis | African barn owl | 1 |
| Tyto alba pratincola | American barn owl | 4 |
| CORACIIFORMES | | |
| Anthracoceros malayanus | White-browed hornbill or Malayan pied hornbill | 1 |
| Lophoceros jacksoni | Jackson's hornbill | 1 |
| PICIFORMES | | |
| Aulacorhamphus sulcatus | Toucanette | 1 |
| Ramphastos ariel | Ariel toucan | 1 |
| Ramphastos carinatus | Lemon-breasted toucan | 3 |
| Ramphastos culminatus | White-breasted toucan | 1 |
| Trachyphonus emini | Emin Pasha's barbet | 1 |
| PASSERIFORMES | | |
| Acridotheres tristis | Common mynah | 1 |
| Aethiopsar cristatellus | Crested mynah | 1 |
| Agelaius icterocephalus | Yellow-headed marsh bird | 1 |
| Aidemosyne cantans | Tawny waxbill | 3 |
| Amandava amandava | Strawberry finch | 18 |
| Amadina fasciata | Cut-throat finch | 13 |
| Amblyrhamphus holosericeus | Red-headed marsh troupial | 1 |
| Bombycilla cedrorum | Cedar wax-wing | 1 |
| Calocitta formosa | Mexican magpie jay | 3 |
| Carduelis carduelis | European goldfinch | 2 |
| Chasmorhynchus nudicollis | Naked-throated bell bird | 1 |
| Chloris chloris | Green finch | 1 |
| Cicinnurus regius | King bird of paradise | 1 |
| Cissilopha yucantanica | Yucatan jay | 1 |
| Colius macrourus | Mouse bird or coly | 1 |
| Corvultur albicollis | White-necked raven | 1 |
| Corvus albus | White-breasted crow | 2 |
| Corvus brachyrhynchos | American crow | 4 |
| Corvus corax sinuatus | Raven | 5 |
| Corvus coronoides | Australian crow | 1 |
| Cosmopsarus regius | Splendid starling | 3 |
| Cyanocitta stelleri diademata | Long-crested jay | 1 |
| Cyanocorax pileatus | Pileated jay | 2 |
| Diatropura progne | Giant whydah | 1 |
| Eremopterix leucopareia | Fischer's finch lark | 1 |

*Birds*—Continued

| Scientific name | Common name | Number |
|---|---|---|
| PASSERIFORMES—continued | | |
| Estrilda melpoda | Orange-cheeked waxbill | 3 |
| | finch | 8 |
| Foudia madagascariensis | Madagascar weaver | 4 |
| Galeopsar salvadorii | Crested starling | 1 |
| Garrulax pectoralis | Black-gorgeted laughing thrush | 2 |
| Gracula javana | Hill mynah | 1 |
| Gracula religiosa | Southern hill mynah | 2 |
| Gymnomystax melanicterus | Bare-jawed troupial | 1 |
| Gymnorhina tibicen | Piping crow-shrike | 1 |
| Heteropsar albicapillus | White-capped starling | 1 |
| Icterus parisorum | Scott's oriole | 1 |
| Lamprocolius s. pestis | Southern glossy starling | 1 |
| Lamprocorax metallicus | Shining starling | 2 |
| Liothrix luteus | Red-billed hill-tit | 1 |
| Melanopteryx rubiginosus | Chestnut weaver | 28 |
| Mino dumonti | Golden-headed mynah | 1 |
| Molpastes haemorrhous | Black-headed bulbul | 2 |
| Munia atricapilla | Black-headed nun | 1 |
| Munia castaneithorax | Chestnut-breasted finch | 1 |
| Munia oryzivora | Java sparrow | 12 |
| Munia punctulata | Nutmeg finch | 20 |
| Otocompsa jocosa | Red-eared bulbul | 3 |
| Paradisea sanguinea | Red bird of paradise | 2 |
| Paradisornis rudolphi | Prince Rudolph's blue bird of paradise | 1 |
| Paroaria cucullata | Red-crested cardinal | 3 |
| Parotia lawesi lawesi | Lawes' six-plumed bird of paradise | 1 |
| Perisoreus canadensis capitalis | Rocky Mountain jay | 4 |
| Pica pica hudsonia | American magpie | 5 |
| Ploceus intermedius | Masked weaver | 7 |
| Poephila personata | Masked grass-finch | 1 |
| Pyromelana orix | Red-crowned bishop bird | 4 |
| Pytilia kirki | East African fire-throated finch | 1 |
| Quelea quelea | Red-billed weaver | 45 |
| Schlegelia wilsoni | Wilson's bird of paradise | 2 |
| Seleucides niger | 12-wired bird of paradise | 2 |
| Semioptera wallacei | Wallace's bird of paradise | 1 |
| Serinus canarius | Canary | 9 |
| Sicalis flaveola | Saffron finch | 2 |
| Steganopleura guttata | Diamond finch | 1 |
| Steganura paradisea | Paradise whydah | 1 |
| Struthidea cinerea | Australian gray jumper | 1 |
| Sturnus vulgaris | Starling | 3 |
| Taeniopygia castanotis | Zebra finch | 1 |
| Uraeginthus bengalus cyanocephalus | Blue-headed blue waxbill | 1 |
| Urobrachya sp | Chestnut-winged whydah | 1 |
| Urocissa occipitalis | Red-billed blue magpie | 3 |
| Vidua macroura | Pintail whydah | 1 |
| Xanthoura luxuosa | Green jay | 2 |
| Xanthoura luxuosa guatimalensis | Guatemala green jay | 2 |

*Reptiles*

| Scientific name | Common name | Number |
|---|---|---|
| TESTUDINATA | | |
| Amyda ferox | Soft-shelled turtle | 8 |
| Chelodina longicollis | Australian snake-necked turtle | 3 |
| Chelydra osceola | Osceola snapping turtle | 1 |
| Chelydra serpentina | Common snapping turtle | 1 |
| Chrysemys picta | Painted turtle | 4 |
| Clemmys insculpta | Wood tortoise | 2 |
| Clemmys marmoratus | Western spotted turtle | 1 |
| Deirochelys reticularia | Chicken turtle | 3 |
| Emys orbicularis | European pond turtle | 11 |
| Geoclemmys spengleri | Loochoo terrapin | 1 |
| Geoemyda thermalis | Senegalese terrapin | 1 |
| Gopherus polyphemus | Gopher tortoise | 6 |
| Kinosternon flavescens | Musk turtle | 3 |
| Kinosternon scorpioides | South American mud turtle | 5 |
| Kinosternon subrubrum | Mud turtle | 15 |
| Pelomedusa galeata | African water tortoise | 17 |

*Reptiles*—Continued

| Scientific name | Common name | Number |
|---|---|---|
| TESTUDINATA—continued | | |
| Pelusios nigricans | Black water tortoise | 3 |
| Pseudemys palustris | West Indian fresh water turtle | 2 |
| Terrapene carolina | Eastern box turtle | 2 |
| Terrapene major | Florida box turtle | 7 |
| Terrapene ornata | Western ornate turtle | 6 |
| Testudo calcarata | Abyssinian tortoise | 1 |
| Testudo ephippium | Duncan Island tortoise | 4 |
| Testudo porteri | Indefatigable Island tortoise | 1 |
| Testudo tabulata | South American tortoise | 9 |
| Testudo vicina | Albemarle Island tortoise | 2 |
| LORICATA | | |
| Alligator mississipiensis | American alligator | 25 |
| Osteolaemus tetraspis | West African broad-nosed crocodile | 6 |
| SQUAMATA | | |
| Suborder—SAURIA | | |
| Conolophus pallidus | Barrington iguana | 1 |
| Conolophus subcristatus | Galapagos iguana | 1 |
| Cyclura cornuta | Rhinoceros iguana | 6 |
| Heloderma horridum | Beaded lizard | 2 |
| Heloderma suspectum | Gila monster | 6 |
| Hydrosaurus pustulosus | Philippine water-dragon | 2 |
| Iguana iguana | Common iguana | 3 |
| Phrynosoma cornutum | Horned lizard | 4 |
| Sceloperus undulatus | Fence or pine lizard | 1 |
| Trachysaurus rugosus | Stump-tailed lizard | 2 |
| Suborder—SERPENTES | | |
| Agkistrodon mokasen | Copperhead | 7 |
| Boa imperator | Emperor boa | 2 |
| Coluber constrictor | Blacksnake | 5 |
| Crotalus horridus | Banded rattlesnake | 2 |
| Epicrates striatus | Haitian boa | 4 |
| Eunectes murinus | Anaconda | 1 |
| Lampropeltis getulus | King snake | 1 |
| Leimadophis parvifrons | Haitian ribbon snake | 2 |
| Masticophis flagellum frenatus | Red racer | 1 |
| Naia nigricollis | Black-necked spitting cobra | 1 |
| Pituophis melanoleucus | Pine snake | 3 |
| Python regius | Ball python | 1 |
| Python reticulatus | Regal python | 5 |
| Python sebae | African python | 4 |
| Sonora occipitalis | Tricolor ground snake | 1 |
| Uromacer sp | Green vine snake | 2 |

*Amphibians*

| Scientific name | Common name | Number |
|---|---|---|
| CAUDATA | | |
| Megalobatrachus maximus | Giant salamander | 2 |
| SALIENTIA | | |
| Bufo marinis | Giant toad | 2 |
| Bufo quercicus | Oak toad | 1 |
| Bufo terrestris | Florida toad | 3 |
| Hyla sp | Tree frog | 10 |
| Leptodactylus pentadactylus | Dominican frog | 5 |
| Xenopus mulleri | East African smooth-clawed frog | 4 |

*Crustaceans*

| Scientific name | Common name | Number |
|---|---|---|
| Cenobita clypeatus (Herbst) | Land hermit crab | 25 |

*Statement of the collection*

| | Mammals | Birds | Reptiles and batrachians | Crustaceans | Total |
|---|---|---|---|---|---|
| Presented | 190 | 142 | 174 | 50 | 556 |
| Born | 56 | 5 | | | 61 |
| Received in exchange | 16 | 15 | | | 31 |
| Purchased | 38 | 56 | 11 | | 105 |
| On deposit | 1 | 1 | 4 | | 6 |
| Total | 301 | 219 | 189 | 50 | 759 |

*Summary*

| | |
|---|---|
| Animals on hand July 1, 1929 | 2,211 |
| Accessions during the year | 759 |
| Total animals in collection during year | 2,970 |
| Removed from collection by death, exchange, and return of animals on deposit | 974 |
| | 1,996 |

*Status of collection*

| | Species | Individuals |
|---|---|---|
| Mammals | 190 | 678 |
| Birds | 327 | 1,046 |
| Reptiles and batrachians | 61 | 247 |
| Crustaceans | 1 | 25 |
| Total | 579 | 1,996 |

VISITORS

The estimated attendance as recorded in the daily reports of the park was about the same as for the preceding year, in spite of the unusually inclement winter weather.

| 1929 | | 1930 | |
|---|---|---|---|
| July | 273,500 | January | 58,950 |
| August | 284,400 | February | 64,150 |
| September | 360,600 | March | 215,700 |
| October | 198,150 | April | 359,175 |
| November | 99,850 | May | 237,200 |
| December | 72,266 | June | 301,200 |
| | | Total visitors for year | 2,525,141 |

The visitors are from every State in the Union and practically all parts of the world.

The attendance of organizations, mainly classes of students, of which we have definite record, was 28,814 from 465 different schools, in 15 States and the District of Columbia, as follows:

| States | Number persons | Number parties | States | Number persons | Number parties |
|---|---|---|---|---|---|
| Connecticut | 70 | 1 | North Carolina | 747 | 16 |
| Delaware | 62 | 3 | Ohio | 151 | 5 |
| District of Columbia | 10,207 | 189 | Pennsylvania | 6,664 | 92 |
| Georgia | 25 | 1 | South Carolina | 293 | 3 |
| Maryland | 4,176 | 58 | Tennessee | 129 | 2 |
| Massachusetts | 438 | 6 | Virginia | 854 | 19 |
| Michigan | 123 | 4 | West Virginia | 550 | 6 |
| New Jersey | 2,960 | 41 | | | |
| New York | 1,365 | 19 | Total | 28,814 | 465 |

Even casual observation of the cars parked in the zoo gives a fair cross section of the visiting public, but many of the local cars visiting the zoo from the District of Columbia, Maryland, and Virginia carry visitors from distant States and from remote parts of the world.

The National Zoological Park serves a higher and more important function than that which is most commonly attributed to it. In addition to being a place for recreation and entertainment, it is an important and unique educational institution. It is unique in that it is a place of study for all ages and degrees of scholarship, from the young child to the veteran naturalist and research man.

Its accumulated data on animals handled over a period of 40 years are constantly referred to. Facts learned regarding animals in the zoo often have a very practical application in other fields of activity.

The beginner in zoology gains at the zoo a grasp of the differences and likenesses between animals, while he rubs shoulders with the advanced medical man studying the primates to help him in solving problems concerned with the health of mankind. The study of parasites and diseases of wild animals in the zoo assists students of parasites and diseases of man and domestic animals in their researches. In short, the National Zoological Park as a laboratory is probably of even greater value to the American people than it is as a recreational area.

## IMPROVEMENTS

A contract was let for the construction of the reptile house, and the work was started in March, 1930. This building promises to be one of the finest of its kind in the world. It will allow the zoo for the first time in its history to maintain a collection of cold-blooded vertebrates as well as certain invertebrates.

During the year many minor improvements have been made in connection with usual maintenance operations. A new type of label is being tried out, and the less legible of the older type are being replaced as rapidly as possible by the new style.

The American waterfowl pond was cleaned by hydraulicking, which restored it to a very satisfactory condition.

The destruction of the old bird house may be considered one of the greatest improvements the park has made in years, but it greatly reduced the housing facilities and no attempt at all has been made to obtain quantities of specimens of the smaller birds and mammals even to replace those lost during the year. There being no empty cages to fill, the zoo has been able to pick and choose in making purchases, so that at the present time the collection contains a great number of interesting rarities, including a number of species unique in American collections.

### NEEDS OF THE ZOO

Quarters for animals remain the most urgent need of the park. The greatest need is for a house in which can be displayed representatives of the large and very interesting group of small mammals. The need for such a house has previously been emphasized.

The National Zoological Park is second to none in natural beauty, and its building program is planned to conserve this by means of constructing a few large, capacious exhibition buildings instead of more numerous small ones, each of the new buildings to house several groups of animals.

Hence, in the small-mammal house it is proposed to provide quarters also for the great apes. The park has an excellent collection of these, but they are now housed in such small cages that they do not appear to the best advantage and can be seen by comparatively few people at one time.

The fire department of Washington has investigated the fire-prevention facilities in the park and finds that the fire hazards are very great on account of inadequate water mains and equipment. Expansion of the water system is therefore very urgently needed as a protection against fire and at the same time to augment the park's inadequate regular supply.

It is now 40 years since the park was established. Much of the woodwork and ironwork in buildings and enclosures constructed in the earlier days, and even comparatively recently, has deteriorated from natural causes and from the unusual conditions present in the zoo, so that we are now confronted with an early and necessary program of replacement. One pair of boilers now 51 years old in the central heating plant have been passed by the boiler inspectors

for only 60 pounds of steam for the present winter, and must be replaced at a very early date. The entire floor in the lion house has been given added support from beneath from time to time, but decay has progressed to such an extent that it is now almost beyond repair and must be replaced in the near future.

Respectfully submitted.

W. M. MANN, *Director.*

Dr. CHARLES G. ABBOT,
*Secretary, Smithsonian Institution.*

# APPENDIX 7

## REPORT ON THE ASTROPHYSICAL OBSERVATORY

SIR: I have the honor to submit the following report on the activities of the Astrophysical Observatory for the fiscal year ended June 30, 1930:

### PLANT AND OBJECTS

This observatory operates regularly the central station at Washington and two field stations for observing solar radiation on Table Mountain, Calif., and Mount Montezuma, Chile. The station at Mount Brukkaros, South West Africa, which was established by the National Geographic Society, is being continued for the present in cooperation with the Astrophysical Observatory with funds donated by a friend of the Institution. In addition, the observatory controls a station on Mount Wilson, Calif., where occasional expeditions are sent for special investigations.

The principal aim of the observatory is the exact measurement of the intensity of the radiation of the sun as it is at mean solar distance outside the earth's atmosphere. This is ordinarily called the solar constant of radiation, but the observations of past years by this observatory have proved it variable. As all life, as well as the weather, depends on solar radiation, the observatory has undertaken the continued measurement of solar variation on all available days. These measurements have now continued all the year round for 11 years. As will appear in this report, recent studies indicate that the permanent continuation of these daily solar-radiation measurements may have great value for weather forecasting. In addition to this principal object, the observatory undertakes spectroscopic researches on radiation and absorption of atmospheric constituents, radiation of special substances such as water vapor, ozone, carbonic-acid gas, liquid water, and others, and the radiation of the other stars as well as of the sun.

### WORK AT WASHINGTON

Continuous series of solar observations having been made as hitherto at several field stations on desert mountains in distant lands, these observations have been critically studied and prepared for publication at Washington. Several new investigations based on these observations have been made during the year.

(*a*) *Reduction of observations.*—The observers in the field at Montezuma, Chile, completely reduce their measurements according to a definitive system adopted several years ago. Telegrams in code arriving daily from Montezuma are decoded and furnished about 24 hours after observing to the United States Weather Bureau, which publishes the solar constant values on the Washington daily weather map. It is planned to include these results also in a broadcast of miscellaneous geophysical data to begin in July, 1930, under the auspices of Science Service.

The variations of solar radiation seldom range beyond 3 per cent, yet, as will appear below, they seem to produce important weather changes even when as small as 0.5 per cent. It is only at high-altitude stations under very tranquil sky conditions that results of sufficient accuracy to display these small solar variations are to be obtained. Although visibly excellent, our station at Table Mountain, Calif. (longitude 117° 41′ W., latitude 34° 22′ N., altitude 7,500 feet), as yet fails to give results of equal consistency to those of the station of Montezuma. A thorough rereduction of all the Table Mountain observations, 1925 to 1930, has been completed, with great labor, during the past fiscal year. But it is disappointing. Fluctuations too evidently produced by the haziness or humidity of the atmosphere still are found occasionally in magnitudes of the order of 2 per cent. Accordingly, a new method of reduction designed to more effectively allow for these atmospheric changes was being developed at the close of the period covered by this report. Preliminary results by it seemed more promising. Reduction of Mount Brukkaros observations is being postponed until the success of this new method is tested for Table Mountain.

(*b*) *Atmospheric ozone.*—As stated in last year's report, one troublesome feature of the Table Mountain work has but lately come to light through the studies of Fowle and of Dobson. It appears that a variation of large percentage occurs in the quantity of atmospheric ozone prevailing at very high levels above Table Mountain. Fortunately only about one-fifth as much change of ozone occurs above Montezuma. The change occurring above Table Mountain is sufficient, if uncorrected for, to introduce nearly 1 per cent change in the results on the solar constant of radiation, but the corresponding effect at Montezuma is negligible.

We were not aware of this source of error when the Table Mountain station was first occupied. It was not until several years after the work began that we introduced there Dobson's method of measuring ozone. Hence, if ozone corrections to solar constant values were to be made from 1925 on, daily, and not merely by averages, as suggested in last year's report, it became necessary to discover a

method whereby the correction could be computed from our daily solar constant observation themselves. This has been done.

Figure 1 shows a portion of the solar energy curve observed at airmass 2.0. The ozone absorption occurs between places 20 and 26 of this curve, but is barely, if at all, visually discernible thereon, even when ozone is most prevalent. However, its effects can be made both discernible and measurable by the following simple procedure. If we take half a dozen of the best days observed in autumn, when the ozone is near its minimum amount, and compute the mean values of the heights of the energy curve in the blue, green, yellow, and red we obtain thereby standard values proportional to the dis-

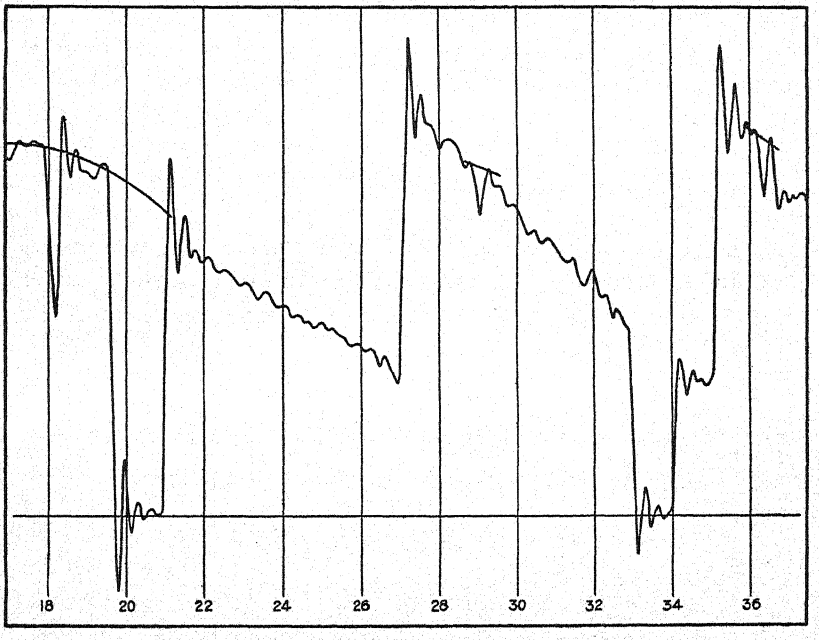



FIGURE 1.—Solar energy curve in the region of absorption by atmospheric ozone

tribution of energy in this region. These standard values, as thus extended from the violet of the spectrum to the red, overlap at each end the ozone region. Next consider the observations of the heights of the energy curve at these selected places on any given day of observation. We divide them by the standard values just referred to and the result is a series of ratios, near unity, but tending sometimes to be lower in the violet than in the red, or vice versa. If plotted against the spectrum place-numbers, these ratios may lie nearly in straight lines. But if the ozone content of the atmosphere on the day examined is different, being larger or smaller, than that of the average of the standard days, then the ratio plot just described presents a loop below or above that straight line which is fixed by

the unaffected spectrum regions in the violet and the red. These facts are illustrated in Figure 2.

The deviation from the straight-line plots of these energy spectrum ratios becomes, then, a measure of the ozone contents of the higher

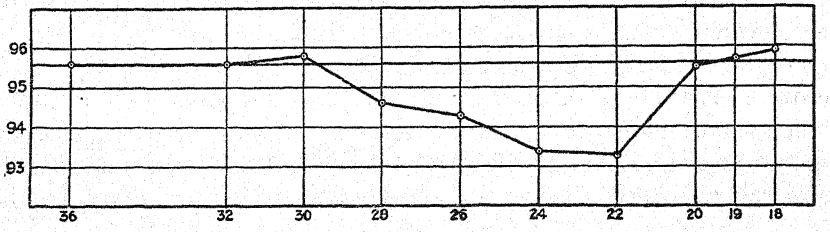



FIGURE 2.—Graph for measuring absorption by atmospheric ozone

atmosphere. The results have been so reduced by us as to give the percentage corrections for ozone absorption to be applied to our solar-constant values on all days of observation at Table Mountain. These corrections apply only to the so-called "short method" of observation. The long method takes cognizance of the ozone absorption in another way.

By the generosity of a friend of the Institution we are preparing to send an expedition to Table Mountain in September, 1930, to

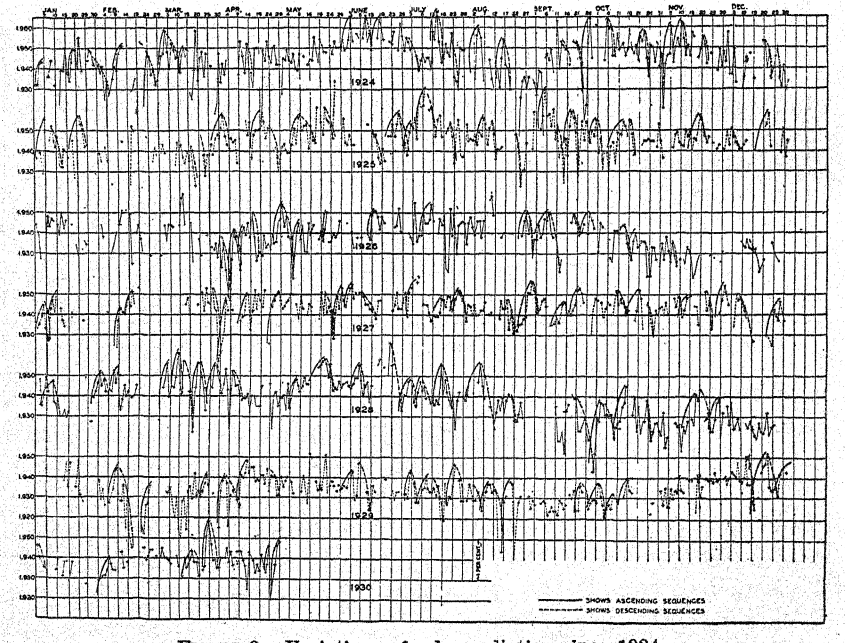



FIGURE 3.—Variations of solar radiation since 1924

make solar observations there through definite known amounts of ozone, so as independently to standardize this new ozone method. The method is applicable on all days when solar radiation work has ever been done.

(*c*) *Solar variation and temperature changes.*—Obviously the weather depends on the sun. If the sun's emission of radiation varies, then the weather must change in some measure on that account. Having six consecutive years of daily observations of solar variation, made and reduced in the most exact way at Montezuma, the variations have been compared with temperature changes in Washington, Williston, and Yuma.

Figure 3 shows the solar radiation measurements at Montezuma since 1924. Satisfactory, nearly satisfactory, and unsatisfactory observations are indicated thereon by circles, crosses, and points, respectively. In passing, I draw attention to the facts that the results

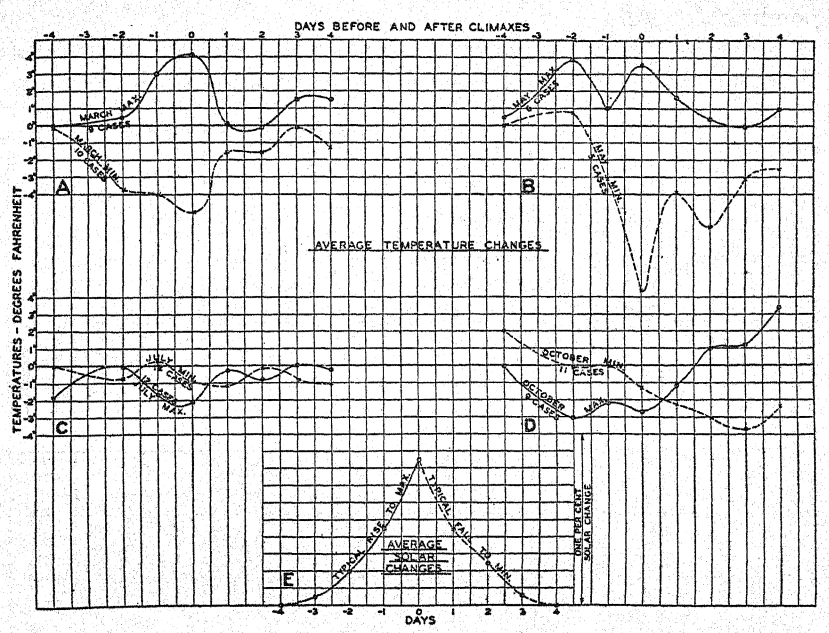



FIGURE 4.—Solar changes and associated temperature changes at Washington

average higher in 1924 and 1925 than in 1929, but return to higher values during the summer of 1930. Also the years 1924, 1926, and 1928, are more affected by long range variations than 1925, 1927, and 1929. This fact tends to verify the 2-year period of solar variation to which I drew attention in last year's report.

What I now particularly note are the numerous cases of sequences of ascending and descending solar radiation values, occupying about 4 days per sequence. These are indicated by curved full and dotted lines respectively in Figure 3. There are 98 cases of ascending and 91 cases of descending sequences thus indicated. If it had been possible to observe on all days, there would probably have been nearly twice as many such sequences. I have omitted cases where the

change was less than 0.4 per cent in the solar constant value, and also have omitted cases depending on isolated or unsatisfactory values.

Corresponding to each of these 189 cases I have tabulated the mean temperature of Washington, Williston, and Yuma, for a 9-day period, of which the day of culmination of the solar change is the fifth or central day. Taking each month of the year by itself, I have computed the average march of temperature over such 9-day intervals. In illustration, I gave Tables 1 and 2, showing the Washington temperature results of March, and Figure 4, which shows, at A, B, C, and D, the mean values for March, May, July, and October. There is given at E the average changes of solar radiation values corresponding thereto.

There are several reversals of sign of the average temperature effects during the year. In Figure 5, I give a study of these changes

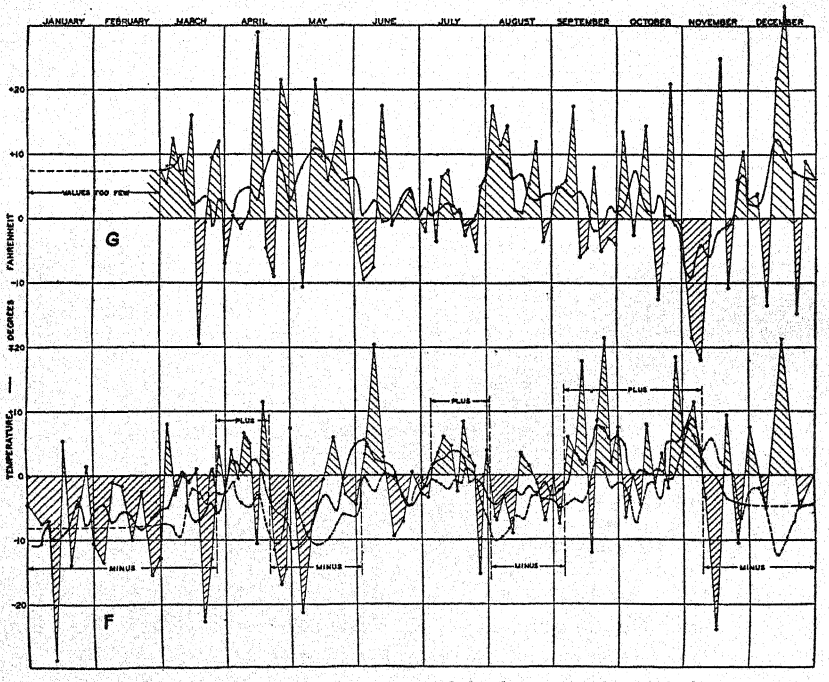



FIGURE 5.—Inversions of temperature dependence on solar variations

of sign at Washington. All the cases have been arranged in consecutive order of days throughout the year, irrespective of what year they occurred. The 98 cases corresponding to ascending sequences are given in Diagram F, and those corresponding to descending sequences in Diagram G. The quantity which is plotted is the difference of temperature between that of the day of culmination of solar change and that of four days previous. To guide the eye as to the prevailing trend of the results, a zigzag line connects the

separate points. The area it includes over the line of zero departures is crosshatched. Obviously the Diagram F has a preponderance of crosshatched area below the zero line, and the Diagram G above. Yet in April, and from June to mid-November, these aspects tend to reverse themselves in each diagram. To bring out this characteristic more plainly, I give in each diagram curves made by taking 5-case consecutive means. That is, the mean is taken of cases 1 to 5, 2 to 7, 3 to 8, and so on. As it seemed clear that such a curve in Diagram G is nearly the reverse of that in Diagram F, I have inverted the 5-day mean curve of G as the dotted curve in F. The correlation coefficient between the full and dotted curves in F is $50 \pm 5$ per cent.

Results are found for Yuma and Williston similar to those presented for Washington. Though the types of effect do not occur in identical months at the three stations, the magnitudes and tendencies are much the same.

## TABLE 1.—*March sequences*

Ascending Sequences

| | | Washington temperatures and departures, degrees Fahrenheit | | | | | | | | | Solar constant values and departures (1.9+tabular values) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Days | | −4 | −3 | −2 | −1 | 0 | 1 | 2 | 3 | 4 | | −4 | −3 | −2 | −1 | 0 |
| YEAR | DAYS | | | | | | | | | | | | | | | |
| 1924 | 4 D. | −13.0 | −5.5 | −10.0 | −6.5 | 0 | +2.5 | −6.0 | −5.5 | −10.0 | D. | −24 | −18 | −12 | −11 | 0 |
| | T. | 34.5 | 42.0 | 37.5 | 41.0 | 47.5 | 50.0 | 41.5 | 42.0 | 37.5 | S. C. | 34 S− | 40 S | 46 S | 47 S | 58 S |
| | 13 D. | −0.5 | −3.0 | −4.5 | +1.5 | 0 | −6.5 | −7.0 | −3.0 | +1.5 | D. | −5 | −2 | −12 | −4 | 0 |
| | T. | 38.5 | 36.0 | 34.5 | 40.5 | 39.0 | 32.5 | 32.0 | 36.0 | 40.5 | S. C. | 45 S | 48 S | 38 S− | 46 S− | 50 S− |
| 1928 | 4 D. | +8.0 | +3.5 | −0.5 | −1.5 | 0 | −4.0 | −5.5 | +6.0 | +6.0 | D. | −28 | ---------- | −12 | −8 | 0 |
| | T. | 45.5 | 41.0 | 37.0 | 36.0 | 37.5 | 33.5 | 32.0 | 43.5 | 43.5 | S. C. | 28 S− | ---------- | 44 S− | 48 U | 56 S− |
| | 9 D. | −5.0 | −6.5 | +5.0 | +5.0 | 0 | 0 | −0.5 | +7.5 | +11.0 | D. | −21 | −16 | −17 | −12 | 0 |
| | T. | 33.5 | 32.0 | 43.5 | 43.5 | 38.5 | 38.5 | 38.0 | 46.0 | 49.5 | S. C. | 40 S− | 45 U | 44 S | 49 S− | 61 S |
| | 20 D. | +1.0 | −1.5 | −2.0 | −3.0 | 0 | +2.0 | +11.5 | +17.5 | +21.0 | D. | −19 | −34 | −12 | 0 | 0 |
| | T. | 39.5 | 37.0 | 36.5 | 35.5 | 38.5 | 40.5 | 50.0 | 56.0 | 59.5 | S. C. | 37 U | 22 S− | 44 S− | 56 S− | 56 S− |
| | 27 D. | +4.5 | +8.0 | +16.0 | +13.5 | 0 | −6.0 | −3.0 | −5.0 | −12.0 | D. | −22 | ---------- | −10 | −11 | 0 |
| | T. | 56.0 | 59.5 | 67.5 | 65.0 | 51.5 | 45.5 | 43.5 | 46.5 | 39.5 | S. C. | 33 S− | ---------- | 45 U | 44 S− | 55 S |
| 1929 | 24 D. | −12.5 | −12.5 | +1.0 | −0.5 | 0 | −10.5 | −3.5 | −15.0 | −14.5 | D. | −8 | −11 | −8 | −4 | 0 |
| | T. | 56.0 | 56.0 | 69.5 | 68.0 | 68.5 | 58.0 | 65.0 | 53.5 | 54.0 | S. C. | 33 S | 30 S | 33 S | 37 S | 41 S |
| 1930 | 17 D. | −6.0 | −14.0 | −20.0 | −11.0 | 0 | +3.5 | −8.5 | −12.5 | −15.5 | D. | −3 | −8 | −6 | −3 | 0 |
| | T. | 53.0 | 45.0 | 39.0 | 48.0 | 59.0 | 62.5 | 50.5 | 46.5 | 43.5 | S. C. | 40 S− | 35 S− | 37 S− | 40 S− | 43 S− |
| | 25 D. | −13.0 | −24.5 | −18.0 | −7.0 | 0 | −17.0 | −14.5 | −12.5 | −9.0 | D. | −27 | −24 | −22 | −7 | 0 |
| | T. | 43.5 | 31.5 | 38.5 | 49.5 | 56.5 | 39.5 | 42.0 | 44.0 | 47.5 | S. C. | 31 S− | 34 S− | 36 S− | 51 S− | 58 S− |
| Means | | −4.06 | −6.28 | −3.67 | −1.06 | 0 | −4.00 | −4.11 | −2.50 | −2.50 | ---------- | −17 | −16 | −12 | −7 | 0 |

## TABLE 2.—*March sequences*

Descending Sequences

| | | Washington temperatures and departures, degrees Fahrenheit | | | | | | | | | Solar constant values and departures (1.9+tabular values) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Days | | −4 | −3 | −2 | −1 | 0 | 1 | 2 | 3 | 4 | | −4 | −3 | −2 | −1 | 0 |
| YEAR | DAYS | | | | | | | | | | | | | | | |
| 1924 | 11 D. | +7.5 | +3.0 | +4.0 | +1.5 | 0 | +6.0 | +4.5 | −2.0 | −2.5 | D. | +14 | +11 | +7 | +10 | 0 |
| | T. | 42.0 | 37.5 | 38.5 | 36.0 | 34.5 | 40.5 | 39.0 | 32.5 | 32.0 | S. C. | 52 S | 49 S− | 45 S | 48 S | 38 S− |
| 1925 | 18 D. | +7.5 | −11.0 | −10.0 | −4.0 | 0 | +9.5 | −1.5 | +2.5 | +1.0 | D. | +17 | +12 | +19 | +9 | 0 |
| | T. | 57.0 | 38.5 | 39.5 | 45.5 | 49.5 | 59.0 | 48.0 | 52.0 | 50.5 | S. C. | 40 S− | 35 S− | 42 S− | 32 S− | 23 S− |
| | 23 D. | +16.0 | +5.0 | +9.0 | +7.5 | 0 | +4.0 | +14.5 | +15.0 | +11.0 | D. | ---------- | 0 | +20 | +10 | 0 |
| | T. | 59.0 | 48.0 | 52.0 | 50.5 | 43.0 | 47.0 | 57.5 | 58.0 | 54.0 | S. C. | ---------- | 28 U | 48 U | 38 S− | 28 S− |
| 1927 | 29 D. | −0.5 | +4.5 | +0.5 | +1.0 | 0 | +3.0 | +8.0 | +1.0 | −4.0 | D. | +28 | +36 | +26 | +25 | 0 |
| | T. | 42.5 | 47.5 | 43.5 | 44.0 | 43.0 | 46.0 | 51.0 | 44.0 | 39.0 | S. C. | 45 U+ | 53 S− | 43 U+ | 42 S− | 17 S− |
| 1928 | 11 D. | +5.5 | +5.5 | +0.5 | +0.5 | 0 | +8.0 | +11.5 | +12.5 | +8.0 | D. | +3 | +8 | +20 | +5 | 0 |
| | T. | 43.5 | 43.5 | 38.5 | 38.5 | 38.0 | 46.0 | 49.5 | 50.5 | 46.0 | S. C. | 44 S | 49 S− | 61 S | 46 S | 41 S |
| | 17 D. | +12.5 | +13.5 | +9.0 | +2.5 | 0 | −0.5 | −1.5 | +1.5 | +3.5 | D. | ---------- | ---------- | +20 | +15 | 0 |
| | T. | 49.5 | 50.5 | 46.0 | 39.5 | 37.0 | 36.5 | 35.5 | 38.5 | 40.5 | S. C. | ---------- | ---------- | 42 S− | 37 U | 22 S− |
| | 23 D. | −20.5 | −17.5 | −15.5 | −6.0 | 0 | +3.5 | +11.5 | +9.0 | −4.5 | D. | +23 | +23 | +16 | +11 | 0 |
| | T. | 35.5 | 38.5 | 40.5 | 50.0 | 56.0 | 59.5 | 67.5 | 65.0 | 51.5 | S. C. | 56 S− | 56 S− | 49 S | 44 S | 33 S− |
| | 31 D. | +12.0 | +6.0 | +9.0 | +7.0 | 0 | +3.0 | +7.0 | +12.5 | +22.0 | D. | +3 | +14 | +9 | −1 | 0 |
| | T. | 51.5 | 45.5 | 48.5 | 46.5 | 39.5 | 42.5 | 46.5 | 52.0 | 61.5 | S. C. | 44 S− | 55 U | 50 S− | 40 U | 41 S− |
| 1930 | 20 D. | +1.5 | +12.5 | +16.0 | +4.0 | 0 | −3.0 | −15.0 | −8.0 | +3.0 | D. | +9 | +12 | +7 | +7 | 0 |
| | T. | 48.0 | 59.0 | 62.5 | 50.5 | 46.5 | 43.5 | 31.5 | 38.5 | 49.5 | S. C. | 40 S− | 43 S− | 38 S− | 38 S− | 31 S− |
| | 29 D. | +9.0 | −8.0 | −5.5 | −3.5 | 0 | +1.0 | −4.5 | +6.0 | +0.5 | D. | +23 | +12 | +4 | +4 | 0 |
| | T. | 56.5 | 39.5 | 42.0 | 44.0 | 47.5 | 48.5 | 43.0 | 53.5 | 48.0 | S. C. | 58 S | 47 S | 39 S | 39 S− | 35 S− |
| Means | | +5.05 | +1.35 | +1.70 | +1.05 | 0 | +3.45 | +3.45 | +5.00 | +3.80 | ---------- | +15 | +14 | +15 | +9 | 0 |

From all this I conclude:

1. An apparent influence of short-period solar variation appears in the temperature of the United States.

2. Corresponding to 0.8 per cent change in the sun, there appear to be temperature changes of the order of 5° F. at Washington.

3. The sign of the correlation changes during the year.

4. A high negative correlation is found between the temperature effects corresponding respectively to rising and to falling solar sequences.

5. The temperature effects coincide in date with the solar changes which appear to induce them.

6. If the connection between solar change and temperature change is a genuine one, it must operate by some indirect atmospheric mechanism; because if it were a direct effect its sign would not change during the year.

7. Although complicated, the relation seems to offer promise for weather forecasting nearly a week in advance. Yet the occasional inversions of effect found inspire caution in a pronouncement of this character. These apparent inversions are, however, doubtless caused frequently by one solar change treading too quickly on the heels of another. Again they may sometimes be caused by delayed receipt from distant centers of action of waves of temperature effect arising from former solar changes.

The results thus far are tentative. It is proposed to study barometric pressures as well as temperatures and to extend the investigation to other parts of the United States and of the world. Preliminary studies have been made, too, of 10-day mean values of solar radiation and temperature, and we hope that in this way, if reliable weather-forecasting data are really secured, they may be extended to months and seasons in advance.

## FIELD STATIONS

Observations of the solar radiation have been continued whenever weather conditions would permit at Table Mountain, Calif., at Mount Montezuma, Chile, and at Mount Brukkaros, South West Africa. All three stations continue to report measurements as made on three-quarters of the days of the year or more. However, not all of these observations prove satisfactory, so that 60 per cent is a better estimate of available observation days for these selected high-level desert stations.

A strange and serious accident occurred in December on Mount Brukkaros. It will be recalled that for the sake of uniformity of

temperature conditions our observatories are in the form either of tunnels in solid rock or cemented chambers under ground. In a hard thundershower on January 24, 1930, the interior of the tunnel in the mountain face was struck by lightning, and the bolometer, the resistance box, and other parts of the electric circuit were burned out. Fortunately a second bolometer and some other spare parts were in stock, so that the observer, Mr. Sordahl, by diligence and clever adaptations, was able to restore the circuits so as to recommence observing with the loss of only four days.

Mrs. Sordahl is keeping an interesting daily journal of events, and, having zoological training, is also making a valuable collection of the fauna and flora of the Mount Brukkaros region for the United States National Museum.

## PERSONNEL

At Washington, Dr. C. G. Abbot continues as director. Finding himself unable to give sufficiently continuous attention to the work, he appointed Mr. L. B. Aldrich to be assistant director, beginning May 19, 1930; F. E. Fowle, research assistant; W. H. Hoover, associate research assistant (detailed to the Division of Radiation and Organisms); Mr. A. Kramer, instrument maker; Mrs. A. M. Bond, statistical assistant, reinstated October 16, 1929, vice Miss M. Marsden, resigned October 10, 1929; Mrs. M. D. (Denoyer) Johnson, computer; Mr. W. Oliver Grant, assistant computer.

In the field: Mr. A. F. Moore, field director, Table Mountain, Calif.; Mr. F. A. Greeley, bolometric assistant, Table Mountain, Calif.; Mr. H. H. Zodtner, field director, Montezuma, Chile; Mr. C. P. Butler, bolometric assistant, Montezuma, Chile; Mr. L. O. Sordahl, field director, Mount Brukkaros, South West Africa; Mr. A. G. Froiland, bolometric assistant, Mount Brukkaros, South West Africa.

## SUMMARY

This year has been notable for both disappointment and achievement. Disappointment—because the high hopes of satisfactory accuracy raised by preliminary results of reduction of observations at Table Mountain proved to some extent illusory, and have given place to tests of new methods designed to remove more effectually atmospheric sources of error. Achievement—in the invention of a new method of determining the amount of atmospheric ozone, applicable on every day in which solar radiation observations have been made; in the discovery of the apparently large and exceptionally important

influence exercised by small short-interval solar variations on terrestrial temperatures; and for the continuation under favorable auspices of observing at the station on Mount Brukkaros, South West Africa.

Respectfully submitted.

C. G. ABBOT,
*Director, Astrophysical Observatory.*

THE SECRETARY,
*Smithsonian Institution.*

# APPENDIX 8

## REPORT ON THE DIVISION OF RADIATION AND ORGANISMS

SIR: I have the honor to submit the following report of progress made by the new Division of Radiation and Organisms during its first year of existence.

The purpose of the division is to undertake those investigations dealing with radiation bearing directly, or indirectly, upon biological problems. The central idea in the development of the division is to build up an especially strong spectrophotometric laboratory, with a staff of experienced physicists and technicians to work cooperatively with men of biological training. Problems undertaken fall into two classes:

1. Direct investigations upon living organisms.
2. Fundamental molecular structure and photochemical investigations related to the biological problems.

Briefly, the following developments have taken place. Basement space in the Smithsonian Building, previously used for storage, has been reconstructed into a modern physical, chemical, and biological laboratory. Equipment has been purchased, and the laboratory appointed. Offices have been furnished and developed in the north tower. A small staff of investigators, of highly specialized training in the various allied fields, has been assembled. Plans have been made, and equipment partially developed for growth of plants under controlled conditions. A preliminary experiment upon the phototropic bending of plants has been carried to completion with interesting results. Equipment has been assembled for a more extensive experiment in this field. In cooperation with the Fixed Nitrogen Laboratory, the near infrared investigation of the halogen derivatives of benzene has been completed.

Arrangements for cooperation with the Department of Agriculture, in carrying out an experiment on the effect of light upon the rooting of Citrus cuttings and the growth of palms, have been consummated. In cooperation with the Research Corporation, staff and shop have been provided for instrumental development.

DEVELOPMENT OF LABORATORY

The initial drafting of plans for the development of the space assigned to the division was begun May 1, 1929. By July 1, the actual work of reconstruction, transforming the empty basement into a laboratory, was under way. Room No. 18, the largest of the three rooms originally assigned, some 60 feet long by 20 feet wide, was planned to accommodate the main plant experiments and spectroscopic work in the visible region. Three small constant temperature rooms were divided off for photometric and phototropic measurements, and control instruments. Provision was made for experiments dealing with the growth of plants under controlled conditions in one end of the long laboratory space remaining. The other end was arranged for the spectroscopic study of the sources of light required in these experiments. Room No. 17, one of the two smaller rooms, was subdivided into two parts, the larger portion, some 16 by 16 feet, was equipped with soapstone sinks, hood, furnace, still, etc., for a chemical laboratory. This is required for the preparation of nutrient solutions which replace the soil in the growth of plants, for dessicating and weighing the plants, for the incidental chemical phases of other experiments, and later, for the photochemical experiments which may be undertaken. The smaller part of room 17, about 9 by 16 feet, has been equipped for glass blowing and related technical construction. Room 16, used prior to the completion of the space in the tower as office and drafting room, was subsequently subdivided into a large laboratory space and two small constant-temperature rooms for infra-red work.

Throughout the laboratory, with the exception of the glass-blowing room, the windows were provided with light-proof curtains, so that the experiments could be carried out in the absence of daylight when required. Plumbing and heavy electrical installations were made so that service would be conveniently available for the experiments. This service includes gas and air, 110 and 220 volts, both alternating and direct current. Alternating current, not previously available in the Smithsonian, was brought in by way of the Freer Building. A special gas booster was installed to provide gas under sufficient pressure for the glass blowing of large pyrex apparatus. A large battery was installed, together with heavy leads for special constant-light sources in the photometer room, and also in the infra-red laboratory. All this general reconstruction, including carpentry, masonry, electrical wiring, plumbing, and painting, as well as the construction of special tables, was carried out either by, or under the direction of, the Museum organization, to whom the division is greatly indebted for the unusually fine laboratory resulting. The

extensive reconstruction of the laboratory space was finally completed toward the end of February, 1930.

The detailed appointment and equipment of the laboratory proved to be a tremendous undertaking, particularly so, because of the border-line character of the proposed investigations. Although the laboratory is not unusually large, provision had to be made for physical, chemical, and biological fields of experimentation. By the middle of July the volume of correspondence involved was such as to require the whole time of a stenographer, thus leading to the employment of Miss Stanley. Mr. Clark, who joined the staff August 1, was of the greatest assistance in the selection of equipment, because of his wide experience in technical fields. During the entire year, a very large part of the director's time was devoted to this phase of the work.

### INITIATION OF EXPERIMENTS

In spite of the construction work which was continuously in progress, steps were immediately taken toward beginning experimental work.

### PLANT GROWTH EXPERIMENTS

Arrangements were made with Maryland University for Doctor Johnston, plant physiologist, to serve in consulting capacity, spending three one-half days a week at the Smithsonian. In collaboration with Doctor Johnston, plans were drawn up for a large preconditioning chamber in which plants could be grown where the individual plants would be under identical conditions, and, at the same time, the humidity and temperature held at a definite point. Plans were also drawn up for individual growth chambers to be mounted in two groups of four. These small growth chambers were to be water-cooled and gas-tight, so as to permit of the rigid control of the atmospheric constituents, as well as temperature and humidity. Windows were introduced for both lateral and overhead illumination. The bases were equipped with adapters for gas-tight connection between the chamber and Mason jars for the nutrient solutions. As the division had no shop facilities, beyond such work as could be carried out as an accommodation through the courtesy of the National Museum and the Astrophysical Observatory, most of the construction had to be arranged for with private concerns. With the growth chambers themselves completed, the extensive development of apparatus for supply and control had to be suspended in March, 1930, for lack of funds. Near the end of the year, in anticipation of new funds on July 1, orders were placed for manifold systems and other equipment required in completing the first set of four chambers.

As artificial light, because of its possibility of rigid control, is used to replace sunlight in most of these experiments, the problem of construction of such special sources becomes a considerable part of the undertaking. Because of his extensive experience in the commercial construction of Neon lamps, as well as his unusual skill in glass blowing, Mr. Clark was added to the staff. By October 1, his glass-blowing laboratory was sufficiently complete to permit the commencement of construction of high vacuum systems to be used in the evacuation of special lamps and thermocouples. The constructive development of these sources will, undoubtedly, be a matter of experimentation which will extend over several years.

### PHOTOTROPIC EXPERIMENTS

As it was early realized that the construction of special growth chambers would be an undertaking extending probably to two years, and undoubtedly requiring more funds than were immediately available, another experiment dealing with the bending of plants in the presence of light was undertaken. This experiment could be carried out through the preliminary stages with equipment immediately at hand. A long constant-temperature room, constructed out of a portion of room No. 18, as has been mentioned, was ideally suited to this purpose. For this phototropic experiment a special photometer box was constructed. Two beams of light, originating at the extremities of the box, played from opposite sides on a central plant. By the introduction of water-cooled filters, these beams were restricted to a narrow range of visible radiation, and provision was made for four possible colors of light.

Even before the completion of the laboratory, actual observations on the phototropic influence of different colors were being made. It was found immediately that beams of equal intensity but different color affected the bending of the plant in markedly different degree. A thermocouple was provided so that by the galvanometer deflection an accurate determination could be made of the relative intensities of the two beams. By adjusting the beam whose color had the lesser influence, its intensity could be increased until a balance was secured against the weaker, but more potent radiation, so that the plant would grow vertically without bending.

Early in the experiment it was realized that the most important disturbing factor was the presence of small temperature fluctuations in the air surrounding the oat sprout whose bending was being observed. After many failures to remove this source of disturbance, which vitiated many of the early observations, a scheme was devised which overcame the difficulty. A double-walled cylindrical glass shield was placed around the sprout, symmetrically, and maintained in continual rotation. Thus, if one side were unevenly heated, its

influence would be carried around so that it was felt equally from all sides. Ultimately, this only proved completely effective when the space between the double walls of glass was filled with water.

In order to determine the wave-length range transmitted by the filters used in the phototropic experiment, spectrograms, secured through the cooperation of the Fixed Nitrogen Laboratory, were taken. These showed the varying amounts of light transmitted by the filter from an incandescent bulb of the type used in the experiment. In order to interpret the spectrograms, a self-registering microphotometer, previously secured by the Astrophysical Observatory, was set up in one of the small constant-temperature rooms. Curves were thus obtained, representing the relative transmission of these filters for the various wave lengths, and so determining definitely the region of the spectrum, or colors, used.

Completion of this preliminary experiment in September of 1930, yielded the following facts: First, that red, or infra-red light, produced no measurable effect; second, that yellow light of the type used, produced a small, but measurable bending; third, that the green light was one thousand times (+ or −2 per cent) more effective than yellow; and finally, that blue light of the range used was thirty times more effective than the green, or thirty thousand times more effective than the yellow.

The outstanding points of interest resulting from the preliminary experiments are two: First, the quantitative reproducibility of the ratios obtained, that is, within 5 per cent of the magnitudes quoted; second, the tremendous ratio observed between yellow and green, together with rapid increase of the effect as one proceeds to shorter wave lengths, tends to indicate a definite threshold wave length at which the phototropic influence shows itself. This is typical of photochemical reactions involving an electronic change of energy. The conclusions drawn from this observation are of far-reaching importance, as this constitutes crucial evidence against any theory which seeks to explain phototropism as merely a thermal effect due to unequal absorption of radiant energy.

The preliminary results of this experiment proved so interesting, even at the early stages, that steps were immediately taken to prepare for a more elaborate experiment. Mr. Hoover, returning from extensive field experience with the Astrophysical Observatory, was assigned to the work of the division in December, 1929. An experienced observer himself, much of the successful carrying out of this phototropic experiment is due to his efforts.

The things which immediately suggest themselves as desirable in a new experiment are, first: To use a narrower wave-length range, or a purer color, in order to determine what wave lengths have a particular effect, and second; to use a larger number of different

wave-length regions, or colors, to determine where in the spectrum the phototropic influence begins as one proceeds to shorter wave lengths that is, from red to blue. For this purpose suitable screens are not available and one must, therefore, turn to a monochrometer. Such a monochrometer would be used, on the one side, to furnish all the different possible wave lengths or colors, while on the other, a single standard comparison source would be used. The phototropic influence of all the various wave lengths, would be expressed in terms of a single standard. As has been seen in the preliminary experiment, some thirty thousand times variation in phototropic effect is to be observed. The comparison light, must, therefore, be varied in intensity over a large range. For this purpose an optical bench has been purchased. By means of this bench, the comparison light may be varied by varying the distance from the plant over a range of three meters. Since the intensity of light varies inversely as the square of the distance from the source, this permits a tremendous range of possible intensities. As funds were not available for the purchase of a monochrometer, plans were made for the construction of an instrument from optical parts available in the Smithsonian. Lenses belonging to the National Museum, and originally used as projectors, were loaned to the division for the construction of this monochrometer. A prism and mirror were loaned by the Astrophysical Observatory. A spectrometer bearing of a novel type, involving an inverted cone with a ball thrust, was constructed by Mr. Kramer in the Astrophysical Observatory shop. Because of the pressure of other work in the shop, this monochrometer, begun in February, was not completed until August of 1930. Preparations for this more extensive experiment are now nearing completion.

### COOPERATION

During the second half of the year, Doctor Weniger from Oregon State College came to the laboratory and undertook the development of more sensitive radiometers for the Astrophysical Observatory. The facilities of the laboratory, and a considerable part of Mr. Clark's time were placed at his disposal. At the termination of the 6-month period, it was necessary for Doctor Weniger to return to his position in charge of the Physics Department at Oregon State College. The completion of the development of these new radiometers is, however, still in progress in his laboratory at Corvallis, Oreg. The radiometers, when finally developed, will not only be of unusual value of the Astrophysical Observatory in its study of stellar radiation, but also to the Division of Radiation and Organisms in its contemplated work in the infra-red spectrum upon the molecular structure of polyatomic molecules.

It will be noted, in this roughly chronological discussion of the work of the year, that the only experiments mentioned came under the first head of direct experimentation on living organisms. Some progress, however, has been made under the second head in the subdivision dealing with molecular structure. Due to the lack of funds and shop facilities, it was impossible to undertake any of this work at the Smithsonian. The only steps taken in that direction were, first: The construction of two large tanks which will be used for vacuum spectrograph bodies, and, second, the provision of special room space in the reconstruction of the basement. Fortunately, however, through the very generous cooperation of the Fixed Nitrogen Laboratory, work begun at the Fixed Nitrogen Laboratory by Doctor Brackett during the four months previous to his appointment by the Smithsonian, has been continued during the past year. Mr. Liddel, appointed as a junior chemist on its staff, has actively pushed the research work contemplated under the direction of and in cooperation with the Smithsonian. The first work undertaken, namely, the study of the near infra-red absorption spectra of the halogen derivatives of benzene, has been carried through to completion so far as available materials and equipment permit. Predictions made in the study of the paraffines in regard to the wave-length position of the absorption due to vibration of hydrogen with respect to carbon, have been borne out in the case of the phenyl derivatives. The position of the second overtone of this vibration promises to furnish an interesting basis for determinating the binding forces upon the hydrogen atoms in different positions in the various organic compounds. The work will be extended during the coming year, largely to nitrogen compounds of a more immediate interest to the Fixed Nitrogen Laboratory, and, at the same time, of great importance in biological connections.

Photochemical work bearing on biological problems can not be undertaken until additional financial support can be obtained. In the infra-red spectroscopic analysis, undertaken at the Fixed Nitrogen Laboratory because of its bearing upon the problems of molecular structure, the range of spectrum which can be studied is limited by the transmission of glass of which the prisms are constructed. It has been the plan to build, at the Smithsonian, spectrographs in which prisms of salt will be used. This will permit the extension of the infra-red investigations from $2\frac{1}{2}\mu$ to $15\mu$. A more complete understanding of the structure of polyatomic molecules will depend upon securing the information from these regions of longer wave lengths, as the most complete possible data upon vibration wave lengths must be secured if progress is to be made. The actual con-

struction of instruments for this purpose was more or less indefinitely postponed for lack of funds and shop facilities as well as laboratory staff. Arrangements for meeting this situation were finally completed toward the end of the fiscal year.

In such an undertaking of border-line investigation, it is not surprising that cooperation should have become a matter of unusual importance. Not only is the division cooperating closely with the University of Maryland in the plant physiological side, with the Fixed Nitrogen Laboratory in the molecular structure work, with the Research Corporation in instrumental development, but also, in a large degree with other bureaus of the Department of Agriculture. Extensive plans have been developed, and something over $1,800 appropriated by the Department of Agriculture for investigation of the effect of various radiation conditions upon the rooting of Citrus fruits and the growth of date palms. This work is under the sponsorship and cooperative direction of Doctor Swingle. It is proposed to complete the second group of four individual growth chambers for that purpose.

### PERSONNEL

During the fiscal year the personnel was as follows:

Research associate in charge, Dr. F. S. Brackett.
Consulting plant physiologist, Dr. Earl S. Johnston.
Research assistant, L. B. Clark.
Research assistant assigned by Astrophysical Observatory, W. H. Hoover.

### SUMMARY

A well balanced and efficient laboratory has been developed. The essential nucleus of a staff has been assembled. An experiment in each of the main fields has been carried through to completion with interesting results. Essential cooperations of a mutually profitable character have been established. Foundations have been laid for extensive investigations of importance in the fields of biophysics and molecular structure. Preparations have been made for making generally available specialized instruments developed by the division.

Respectfully submitted.

F. S. BRACKETT,
*Research Associate in Charge.*

Dr. C. G. ABBOT,
*Secretary, Smithsonian Institution.*

# APPENDIX 9

## REPORT ON THE INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE

SIR: I have the honor to submit the following report on the operations of the United States Regional Bureau of the International Catalogue of Scientific Literature for the fiscal year ending June 30, 1930.

Since publication of the catalogue was suspended by the London Central Bureau, owing to advanced costs in printing and the inability of the cooperating European countries to meet these advances with their depreciated and unstable financial resources, it has been the policy of this bureau to spend only so much of its annual congressional appropriation as is necessary to keep the organization alive pending the time when reorganization is possible and publication can be resumed. The gross expenditure for the past year was $5,457.96 out of the appropriation of $7,885.

In the several preceding reports conditions affecting the catalogue due to the late war were noted, and in the last report definite suggestions were made regarding possible means of refinancing the enterprise and estimates of the sum needed were submitted. Owing to the still unsettled political and financial conditions abroad, no definite scheme for reorganization has yet been submitted by the director of the central bureau or the chairman of the executive committee, in whom authority for this purpose is vested.

The proposals looking toward reorganization made in the last annual report were discussed in an article entitled "The International Catalogue of Scientific Literature Again," by Dr. Ernest Cushing Richardson, consultant in bibliography and research, Library of Congress, published in "Science," June 20, 1930 (Vol. LXXI, No. 1851 pp. 635–637), and as Doctor Richardson is one of the great international authorities on bibliography and on the needs of librarians it is thought advisable to quote at length his remarks, hoping thereby to aid the effort being made to refinance the catalogue.

THE INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE AGAIN

The proposal suggested by the Smithsonian Institution to revive the publication of the International Catalogue of Scientific Literature on a very modest but well-considered budget is a challenge to all scientists and librarians, and to all trust agencies which are spending good money for the promotion of research.

It is suggested that a revolving fund of $75,000 and 1,000 library subscriptions of $50 for 17 volumes will insure the enterprise. Whether or not this is enough is a detail. If this catalogue or something like it is an indispensable tool for research, as many first-class scientists seem to think, then any necessary amount should and probably can be had. If the catalogue is not needed, too much money is now being spent on it. Why waste more?

The Smithsonian raises this question plainly. Why ask the American Government to continue to appropriate six or seven thousand dollars a year in the procrastinated hope of a resurrection, if the project is better dead? If it is needed, why procrastinate?

By putting the question the Institution has deserved the thanks of all concerned. It is to be hoped that it will not let the matter rest until it has a square answer from all responsible parties. * * *

* * * The question raised by the Smithsonian is not the question of presenting a new project to be justified, financed and initiated, but whether perfectly good machinery worth at least $3,000,000 is to be scrapped, in an enterprise bound to be revived sometime, as Professor Armstrong, of the Royal Society, prophesies and as many scientific bibliographers in many countries are on record as believing.

It is at this point that the overture of the Smithsonian becomes a matter of practical business concern both in the research trust endowments and to the libraries. The research endowments are bombarded with bibliographical projects of varying method and degrees of merit. They aid or support a good many projects. They are deeply concerned as trust organizations to put their money where it will do the most good. Other things being equal they prefer to put it where one dollar will do the work of four. This seems to be a spot where one million, perhaps a quarter of a million, will do the work of four millions. If its usefulness merely averages with these other projects the endowments are likely to feel that its claims come first. It is here they can give the most bibliographical service with the least money. The proposition touches the libraries in a very similar way. If and when the matter is revived it will depend for financing, if not on the endowments, then on library subscriptions. If this machine is scrapped, when a new one is started either a $3,000,000 endowment must be had from promoters of research or a quadruple price charged to libraries.

This leads straight to the crucial question of whether the international catalogue is in fact a primary, essential or indispensable tool in such sense that it is bound to be revived sometime. It no doubt seems a futile and mortifying matter to those who have been deeply engaged in the problem for 30 years that they should have to rejustify and refight a matter which was fought to the finish 30 years ago. But it is fair enough. It is not the only real bibliographical need of science. There are at least two other equally well-defined needs—abstracts and handbooks. Without disparaging the usefulness of these two other tools, it must be confessed that a good case is made by those who claim that something like the international catalogue is the essential and only indispensable tool among the three types.

A dispassionate general bibliographer must recognize that this is a conclusion towards which the whole history of bibliographical experience tends. The complete survey, in full title form, of the whole literature of any subject or group of subjects is the only solution of the main need of the student in research and in the higher learning, that is, completeness, and the best solution as to his need for a perspective. * * *

In short, bibliographical experience confirms the judgment that something "very like" this catalogue as to completeness is the essential, and full title method best, without prejudice as to variety in other details. * * *

Scientific bibliography has the very high honor in bibliographical history of having been the first to conceive and to carry out on a large scale in the international catalogue the seeing-as-a-whole aspect of things which the modern school of psychologists is now exploiting. It would be an even greater honor if it should lead the promotors of research generally to apply the comprehensive method to other large fields.

Notwithstanding the practical deadlock still existing in international relationships, where cooperation is essential to success, it is hoped and expected that some method will be found to reorganize and finance this great enterprise, as its history and past success entitles it to first place when worth-while projects are being considered by private individuals or by existing foundations whose aim and purpose is to aid the advance of knowledge and the welfare of mankind.

Respectfully submitted.

LEONARD C. GUNNELL,
*Assistant in Charge.*

DR. CHARLES G. ABBOT,
*Secretary, Smithsonian Institution.*

# APPENDIX 10

## REPORT ON THE LIBRARY

SIR: I have the honor to submit the following report on the activities of the library of the Smithsonian Institution for the fiscal year ended June 30, 1930:

### THE LIBRARY

The Smithsonian library, or library system, is composed of the 10 major and 36 minor libraries of the Institution. It numbers somewhat more than 800,000 volumes, pamphlets, and charts, of which many are on art, literature, history, music, and philosophy, but most on science and technology. The system is especially strong in serial publications and in the reports, proceedings, and transactions of the learned societies and institutions of the world. The major units are the Smithsonian deposit in the Library of Congress, the Smithsonian office library, the Langley aeronautical library, and the libraries of the United States National Museum, the Bureau of American Ethnology, the Astrophysical Observatory, the National Gallery of Art, the Freer Gallery of Art, the Division of Radiation and Organisms, and the National Zoological Park. The minor units are the sectional libraries of the National Museum. The system, with its highly specialized collections, the gathering of which has been proceeding since 1846, the date when the Smithsonian began its work, has brought to the Institution and through it to the Government and to American scholars generally the results of the research of the world during its most important scientific era, and thus has contributed not a little to the fulfilment of the purpose for which the Institution was founded, namely, that of increasing and diffusing knowledge among men.

### CHANGES IN STAFF

A number of changes occurred in the staff. Miss Isabel L. Towner, assistant librarian in the National Museum, after several years of noteworthy service, resigned to accept an editorial position in New York. She was succeeded by Miss Leila G. Forbes, a graduate of St. Lawrence University and of the Pratt Library School, who had been for many years librarian of Randolph-Macon Woman's College.

Miss Ethel A. L. Lacy, assistant librarian in the National Museum, also resigned to take a position in another Washington library. Her

place was filled by the appointment of Miss Gertrude L. Woodin, a graduate of Wellesley College and of the Albany Library School, who had been for some time a junior librarian on the roll of the International Exchanges. Mrs. Hope Hanna Simmons, junior library assistant in the National Museum, was promoted to the vacant junior librarianship. Mrs. Mary Arnold Baer, under library assistant in the Museum, was advanced to Mrs. Simmons' former position. Miss Margaret Moreland, a graduate of the library science department of George Washington University, who was already serving temporarily on the roll of the International Exchanges, was selected to succeed Mrs. Baer.

Miss Anna M. Link, a former teacher, and at present a student of library science at George Washington University, was appointed to the position of minor library assistant in the Astrophysical Observatory. Mr. William O. Grant, assistant messenger in the National Museum, was given a better position elsewhere in the Institution, and Mr. Stephen Stuntz took his place. The temporary employees were Mr. Alan Blanchard, Mrs. Daisy Cadle, Miss Rosalie Dimmette, Miss Katherine Everhart, Miss Angela Moore, Miss Margaret Moreland, Mrs. M. Landon Reed, Miss Jennette Seiler, Miss Eleanor Spielman, and Mrs. M. Frances Watkins.

### EXCHANGE OF PUBLICATIONS

In the early days of the Institution the accessions to the library usually came by purchase, gift, or copyright—for in those days the copyright law provided that one copy of each new book published in the United States should be deposited in the Library of Congress and one in the Smithsonian library. Increasingly, however, since that time the accessions have come by exchange of publications with editors of journals and with learned institutions and societies, until now, while some are still obtained by purchase and gift, by far the greater number are received in exchange. Many of the latter come through the United States International Exchange Service, which is administered by the Institution.

During the fiscal year just closed the Smithsonian library received 24,063 packages by mail and 2,077 through the Exchange, each containing one or more publications. These were stamped and entered—with the exception of the documents from foreign governments—and assigned to the units of the library system in which they would be of most use in furthering the work of the Institution and its branches, but chiefly, of course, to the Smithsonian deposit and the library of the National Museum. There were a number of unusually large sendings, the largest being one of 208 pieces from the Academy of Sciences at Heidelberg. This went far toward completing the set of the Academy's publications in the deposit.

Among the items received were several thousand dissertations from the universities of Basle, Berlin, Bern, Bonn, Breslau, Budapest, Erlangen, Freiberg, Giessen, Greifswald, Halle, Heidelberg, Helsingfors, Jena, Johns Hopkins, Kiel, Königsberg, Leipzig, Lund, Marburg, Neuchâtel, Pennsylvania, Rostock, Strasbourg, Tübingen, Utrecht, Würzburg, and Zürich; and from technical schools at Berlin, Bonn, Braunschweig, Delft, Dresden, Freiberg, and Karlsruhe.

Most of the 1,711 letters written by the library staff during the year—which, by the way, represented an increase of about 400 over the previous year—had to do with the acquisition of this material. Many of these involved careful checking of sets and reviewing of earlier correspondence. Some proposed or accepted exchange for new publications. This gratifying increase in the number of letters written by the library was effected largely by the recent reorganization of the accessions department. As the immediate result of this increase the exchange correspondence of the library was brought practically up to date. Most of the letters were prepared in response to special requests for publications needed by the Smithsonian deposit and the libraries of the National Museum and the Astrophysical Observatory. The number of items thus obtained was 2,928.

### GIFTS

As usual, there were many gifts. The largest one came from Mr. James Townsend Russell, jr., honorary collaborator in old world archeology in the National Museum, who presented to the Institution 1,400 volumes on different subjects, together with a collection of music. These will be assigned mainly to the Smithsonian deposit, the office library, and the libraries of the National Museum and the National Gallery of Art. About 150 volumes and 1,000 periodicals, chiefly on aeronautics, came from the National Aeronautic Association; and 2,000 or more miscellaneous scientific publications from the American Association for the Advancement of Science, the American Association of Museums, the Anthropological Society of Washington, the Geophysical Laboratory, the Hygienic Laboratory, the International Catalogue of Scientific Literature, the Philosophical Society of Washington, and the Library of Congress. Another important gift was that of 58 volumes on Japanese history and literature, from the Historiographical Institute, Tokyo.

Among other gifts were 60 volumes, largely in the field of mining engineering, from Mr. A. F. G. Lucas, and copies of the following: Mythology of All Races, volumes 2, 3, 4, 7, 8, and 11, by various authors, from the Archæological Institute of America and the Marshall Jones Co., of Boston; The Birds of Tropical West Africa, volume 1, by David Armitage Bannerman, from the Crown Agents for the Colonies on behalf of the Governments of Gambia, Gold

Coast, Nigeria and Sierra Leone; Milestones, 1830–1930, from the Boston Society of Natural History; The Life and Work of George H. Corliss, by the American Historical Society, from Miss Mary Corliss; A Narrative of Colonel Ethan Allen's Captivity, Containing His Voyage and Travels Written by Himself, from the Fort Ticonderoga Museum; Taking One's Own Ship Around the World, by William K. Vanderbilt, from the author; The Naturalist in Nicaragua, by Thomas Belt, from Mr. Michael J. Clancy; An Early American Queen Anne Escritoire, 1715–1730, by Ross H. Maynard, from the author; Air Pioneering in the Arctic—the Two Polar Flights of Amundsen and Ellsworth—by Lincoln Ellsworth, from the author; Archaeologia Orientalis, volume 1, Prehistoric Sites by the River Pi-liu-ho, South Manchuria, by Kosaku Hamada, from the Far-Eastern Archaeological Society, Tokyo; Av Hvalfangstens Historie, by Sigurd Risting, from the author; The Genealogical Record of the Schwenkfelder Families, edited by Samuel K. Brecht, from Mr. Wayne C. Meschter; Memorials of Peter A. Jay, compiled by his great-grandson, John Jay, from Mrs. John Jay; An Introduction to Biblical Archaeology, by George S. Duncan, from the author; The Barbary Voyage of 1638, Now first Printed from the Original Manuscript of Sir George Carteret, from Mr. Boies Penrose; History of the Natural History Society of Northumberland, Durham and Newcastle-upon-Tyne, 1829–1929, by T. Russell Goddard, from the Society; Smithsonian Scientific Series, Patrons' Edition, volumes 5 and 6—Insects, Their Ways and Means of Living, by R. E. Snodgrass, and Wild Animals In and Out of the Zoo, by W. M. Mann—from the Smithsonian Institution; Catalogue of Madreporarian Corals, Volume VII—A Monograph of Recent Meandroid Astræidæ—by George Brook and H. M. Bernard, from the British Museum; Researches in Prehistoric Galilee, 1925–1926, by F. Turville Petre, and A Report on the Galilee Skull, by Sir Arthur Keith, from the British School of Archæology in Jerusalem; and United States Geological Exploration of the Fortieth Parallel, 1870–1880, volumes 1–7, with Geographical and Topographical Atlas, by Clarence King, from Mrs. Frederic V. Abbot.

Donors on the staff of the Smithsonian Institution were Secretary Abbot, Assistant Secretary Wetmore, Dr. William H. Holmes, director of the National Gallery of Art, Dr. Marcus Benjamin, Mr. A. N. Caudell, Mr. A. H. Clark, Mr. P. E. Garber, Dr. J. W. Gidley, Dr. O. P. Hay, Dr. Aleš Hrdlička, Mr. N. M. Judd, Dr. W. R. Maxon, Dr. G. S. Miller, Mr. A. J. Olmsted, Miss Mary J. Rathbun, Mr. W. de C. Ravenel, Dr. C. W. Richmond, Mr. J. R. Riley, Mr. J. T. Russell, jr., and Dr. W. L. Schmitt. Mrs. Charles D. Walcott also gave the library a number of publications.

## SMITHSONIAN DEPOSIT

The Smithsonian deposit in the Library of Congress is the main unit in the library system of the Institution. It dates from 1866, when for various reasons Congress granted authority to the Smithsonian to deposit its library of 40,000 volumes in the Library of Congress. Since that time the collection has been steadily increased by sendings from the Institution until it now numbers more than a half million volumes, pamphlets, and charts, together with thousands of volumes still uncompleted. The deposit comprises works relating to many branches of knowledge, but chiefly to the natural and physical sciences, and includes a collection of scientific serials and of the publications of learned institutions and societies that is unique for completeness among groups of its kind. Most of the items have come to the Institution during its 80 years and more of existence in exchange for its publications and those of the Government bureaus under its direction. In 1900 the Library of Congress established a special division, known as the Smithsonian division, to take charge of the scientific publications in the deposit, as well as of similar works belonging to the library itself. The rest of the publications are shelved in the other divisions of the library according to subject. It follows that the Smithsonian deposit is not, as many have supposed, synonymous and coextensive with the Smithsonian division.

In the course of the year just closed the library of the Institution forwarded to the deposit 19,144 publications, consisting of 2,720 volumes, 11,802 parts of volumes, 4,352 pamphlets, and 270 charts. Among these were 2,205 publications that the Smithsonian library had obtained in exchange for the deposit, in response to want cards sent from the order division, periodical division, and Smithsonian division, or more than two and one-half times the number obtained in the fiscal year 1929 and nearly five times the number in 1928. Among them, too, were 4,484 dissertations. The library also forwarded 13,729 documents of foreign governments, without stamping or entering them, to the division of documents. The total number of publications, therefore, added to the Library of Congress during the year by the Smithsonian library was 32,873—an increase of nearly 10,000 over the year before. This noteworthy increase, which was due primarily to the reorganization of the accessions department already referred to, was due also, in no small measure, to the hearty cooperation the library staff received from those in immediate charge of the various divisions of the Library of Congress chiefly concerned, notably the Smithsonian division.

## NATIONAL MUSEUM LIBRARY

The library of the United States National Museum, which consists of two major collections—namely, on natural history and technology—shelved respectively in the Natural History Building and the Arts and Industries Building, and of 36 minor collections scattered among the various sections of the Museum, is, next to the Smithsonian deposit, the largest and most important unit in the Smithsonian library system. It numbers 76,879 volumes and 108,297 pamphlets. During the last fiscal year it was increased by 2,317 volumes and 668 pamphlets. Most of these came in exchange, but many were purchased and some were received as gifts.

The staff had a very busy year. They entered 8,805 periodicals, catalogued 1,146 volumes and 856 pamphlets, and added 4,493 cards to the catalogue of the natural history library and 295 to that of the technology library. They assigned to the sectional libraries 5,622 publications, and lent to the Museum staff and other Smithsonian employees 7,745, of which 2,820 were charged at the recently established loan desk in the Arts and Industries Building. Of the loans, 1,889 were borrowed from the Library of Congress and 246 elsewhere. The number of publications returned to the Library of Congress was 2,250, and to other libraries 241. The loans to Government libraries and to libraries outside of Washington were 181. Among the latter were those of the American Museum of Natural History, the New York Botanical Garden, and the Department of Agriculture, Ottawa, Canada, and of the following colleges and universities: Buffalo, California, Goucher, Harvard, Johns Hopkins, MacMaster (Toronto), Massachusetts Institute of Technology, Minnesota, North Carolina State, Princeton, and Tennessee. The number of volumes prepared for binding was 2,071, of which 1,271 were bound. The others will be sent to the bindery when additional funds become available early in the next fiscal year. This work entailed considerable checking of sets, collating, and correspondence. In this connection it is of interest to note that the library was able to obtain, without expense, 668 volumes and parts lacking in its sets by writing special letters to the journals and learned societies concerned.

The reference use of the library, not only by those connected with the Smithsonian Institution and the different branches of the Government, but also by students and the public in general, increased somewhat over that of the year before and necessitated a corresponding increase of work on the part of the staff. Hundreds of inquiries for information of various kinds were received and answered. To the technology library alone, with its 700 visitors for the year, out-

side of the Smithsonian employees, came about 225 such inquiries, while to the natural history library came many more.

The sectional libraries, which number 36, are the immediate working tools of the curators and their assistants. Many of them are rich in highly specialized material, much of which has not been catalogued. These libraries present other problems, too, that are pressing for solution, and one of their most urgent needs is of two assistants who can be detailed from the main library to spend their full time looking after the interests of these smaller but very important library units. During the past year it was possible for the library staff to find time for only a few pieces of work in these libraries, such as preparing 2,680 cards for the pamphlet collection in the division of mammals, aiding the department of geology in increasing quite materially its set of the publications of the various State geological surveys, and cooperating with the scientific staff of the division of plants in reorganizing the library of that division, especially by arranging 10,000 cards for its reference file and getting the John Donnell Smith botanical collection ready for transfer to its shelves. This included the making of a catalogue of the collection.

These libraries are as follows:

Administration.
Administrative assistant's office.
American archeology.
Anthropology.
Biology.
Birds.
Botany.
Echinoderms.
Editor's office.
Ethnology.
Fishes.
Foods
Geology.
Graphic arts.
History.
Insects.
Invertebrate paleontology.
Mammals.
Marine invertebrates.
Mechanical technology.
Medicine.
Minerals.
Mineral technology.
Mollusks.
Old World archeology.
Organic chemistry.
Paleobotany.
Photography.
Physical anthropology.
Property clerk's office.
Reptiles and batrachians.
Superintendent's office.
Taxidermy.
Textiles.
Vertebrate paleontology.
Wood technology.

## OFFICE LIBRARY

The office library serves Smithsonian employees in two ways. It keeps constantly on hand in the administrative offices, reading rooms, and other convenient places many works of general reference, including dictionaries, encyclopedias, atlases, and sets of Smithsonian and other learned publications; it also provides material, to a limited

extent, of a less technical character, designed mainly for a cultural and, in some instances, even a recreational purpose. Most of the publications in the latter group have been received as gifts from employees of the Institution or from friends outside. During the last year several hundred such publications were given to the Institution, especially by Mr. J. Townsend Russell, jr., of the scientific staff of the National Museum. These will soon be catalogued and placed on the shelves of the office library. The happy arrangement previously made with the Library of Congress to lend to the library from time to time for a brief period some of the latest popular and semipopular books was continued, much to the satisfaction of the Smithsonian employees. To the office library were added 1,938 volumes and 316 pamphlets. Its periodical entries were 835.

### BUREAU OF AMERICAN ETHNOLOGY LIBRARY

The library of the Bureau of American Ethnology, which is housed in the Smithsonian Building, is one of the more important units in the library system of the Institution. It is made up, in the main, of works on anthropology, not a few of which are quite rare. It is particularly rich in publications on the archeology, history, myths, religion, arts, sociology, language, and general culture of the American Indians. The collection has some valuable manuscripts, many photographs, and several Indian vocabularies. The library numbers 29,071 volumes and 16,527 pamphlets. During the last year it was increased by 559 volumes and 150 pamphlets. The number of periodicals entered was 4,106, and the number of volumes bound 210. The additions to the card catalogue were 3,420. The loans were 840. As usual, hundreds of publications were consulted in the library, especially by members of the bureau staff, and considerable reference work was done by those in charge of the collection.

### ASTROPHYSICAL OBSERVATORY LIBRARY

The library of the Astrophysical Observatory, while one of the smaller units in the library system, consists of publications of especial value in the astrophysical and meteorological work of the Institution. The main part of the collection is shelved in the Smithsonian Building, the rest in the observatory itself, where it is immediately available for the use of the investigators. Its file of current periodicals is also kept in the observatory, as is the card catalogue of the library. The collection numbers 4,008 volumes and 3,100 pamphlets. To it were added during the last year 140 volumes and 151 pamphlets. The number of volumes bound was 50.

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### RADIATION AND ORGANISMS LIBRARY

The library of radiation and organisms, which was established in 1929 as a major unit of the Smithsonian library system to meet the needs of a branch of research recently organized under a separate division of the Institution, made satisfactory progress during the year. An excellent working nucleus of reference books was obtained for it, and arrangements were made to receive regularly the outstanding magazines in the field of the division's special interest. A dictionary card catalogue was begun for the collection. At the end of the year the library numbered 74 volumes, 8 pamphlets, and 6 charts, besides about a hundred unbound periodicals.

### LANGLEY AERONAUTICAL LIBRARY

During the year the Institution's famous collection of aeronautical publications, known as the Langley aeronautical library, was removed from the main hall of the Smithsonian Building, where it had been kept for many years, to the Library of Congress. There, with other and larger collections of its kind, it will be more centrally available to the technician and historian as well as the general student.

The collection will be under the immediate supervision of the chief of the newly organized division of aeronautics, in the development of which the Guggenheim fund has recently taken a generous interest. But it will remain a unit of the Smithsonian library system—a second deposit in the Library of Congress, distinct from the main unit of that system known as the Smithsonian deposit, but subject to the same conditions that Congress specified in providing for the establishment of the older and larger deposit. Its identity will be shown by a special stamp and book plate, and the collection will continue to bear the name of the Langley aeronautical library and will be increased from time to time by sendings from the Smithsonian—it being the desire of the Institution to preserve the collection as an independent and growing memorial to its third secretary, whose work marked the beginning of the scientific study of aeronautics in the United States.

Many of the library's rarest items once belonged to Secretary Langley; others to such well-known investigators and experimenters as Alexander Graham Bell, Octave Chanute, and James Means. The library numbers 1,734 volumes and 923 pamphlets and includes files of most of the early aeronautical magazines, together with a large number of photographs, letters, and newspaper clippings. It was increased the past year by 37 volumes, 362 parts of volumes, and 85 pamphlets.

### NATIONAL GALLERY OF ART LIBRARY

When in 1920 the National Gallery of Art was set apart as a separate Government bureau under the administrative charge of the Smithsonian Institution, its library ceased to be a sectional library of the National Museum and became a major unit of the Smithsonian library system. Since that time the collection, already an important nucleus of works on fine art, both American and foreign, has grown yearly by carefully selected additions, until it now contains 1,098 volumes and 1,166 pamphlets. Small as the collection still is, it almost fills the space available for books in the present limited gallery quarters in the Natural History Building and will soon need more room there unless in the early future a special building is provided for the gallery. When that is at hand, the collection can be adequately shelved, and be permitted to grow more rapidly, to meet the expanding needs of the gallery. The library was increased during the year just closed by 97 volumes and 60 pamphlets. Most of these were purchased or received in exchange, but not a few were gifts, especially from Dr. William H. Holmes, director of the gallery. The number of periodicals entered was 271.

### FREER GALLERY OF ART LIBRARY

The library of the Freer Gallery of Art is one of the most unique in the Smithsonian library system. Centering, as it does, primarily in the interest of the Freer Gallery in the arts and cultures of the Far East, India, Persia, and the nearer east, it richly supplements for the purpose of research—especially with its publications in the Chinese and Japanese languages, some of which are very rare—the corresponding collections in the Library of Congress. It also has to do somewhat with the life and works of various American painters, notably James McNeill Whistler, many of whose pictures are the possession of the gallery, and with the famous biblical manuscripts of the fourth and fifth centuries, known as the Washington Manuscripts, which the gallery is so fortunate as to own.

The main collection numbers 4,362 volumes and 2,998 pamphlets; the special collection designed for the use of the field staff of the gallery, 814 volumes and 500 pamphlets. The former was increased during the last fiscal year by 93 volumes and 229 pamphlets. The number of volumes bound was 29. During the year, thanks to the generous cooperation of the gallery, the work of reclassifying and recataloguing the library was undertaken. In this connection 1,134 cards were prepared and filed in the new dictionary catalogue. This work will be continued the coming year.

### NATIONAL ZOOLOGICAL PARK LIBRARY

The library of the National Zoological Park is made up of publications that have to do chiefly with the habits and care of animals, and is designed for the use of the director and those associated with him. It numbers 1,213 volumes and 403 pamphlets. Its accessions for the year were 4 volumes and 3 pamphlets.

### SUMMARY OF ACCESSIONS

The accessions for the year may be summarized as follows:

| Library | Volumes | Pamphlets and charts | Total |
|---|---|---|---|
| Astrophysical Observatory | 140 | 151 | 291 |
| Bureau of American Ethnology | 559 | 150 | 709 |
| Freer Gallery of Art | 93 | 229 | 322 |
| Langley Aeronautical | 37 | 85 | 122 |
| National Gallery of Art | 97 | 60 | 157 |
| National Zoological Park | 4 | 3 | 7 |
| Radiation and Organisms | 74 | 14 | 88 |
| Smithsonian deposit, Library of Congress | 2,720 | 4,622 | 7,342 |
| Smithsonian office | 1,938 | 316 | 2,254 |
| United States National Museum | 2,317 | 668 | 2,985 |
| Total | 7,979 | 6,298 | 14,277 |

The approximate number of volumes, pamphlets, and charts in the Smithsonian library system on June 30, 1930, was as follows:

| | |
|---|---|
| Volumes | 571,085 |
| Pamphlets | 186,484 |
| Charts | 25,261 |
| Total | 782,830 |

This total does not, of course, include the large number of volumes in the system still uncatalogued or awaiting completion.

### UNION CATALOGUE

Further progress was made on the union dictionary catalogue begun a short time ago. This will require many years to complete, but when it is finished it will be an invaluable instrument in the reference activities of the Institution, for it will constitute a central author-title-subject finding list, for the most part on Library of Congress cards, of all the items in all the 46 Smithsonian libraries. Unfortunately, with the present force, the progress of this work must continue to fall short each year of what we should like.

Notwithstanding this fact, however, the staff, besides keeping up with the current work, was able to finish cataloguing the important John Donnell Smith botanical collection, with the exception of one set of pamphlets and reprints, and to make considerable headway in cata-

loguing the library of the Freer Gallery of Art. This work involved classifying the publications and mounting many of them in pamphlet binders. The staff spent some time in checking the Langley aeronautical collection and making the necessary changes in the catalogue cards incident to the transfer of that library to the Library of Congress. It worked out a plan by which the Library of Congress can obtain copies of certain cards prepared by the staff for filing in its union catalogue. It also provided that Library with manuscript copies of a goodly number of titles, to be printed and distributed with the cards regularly issued by the Library. In addition, it added more than 15,000 cards to the shelf list of the Museum library, thus advancing it to a point from which it can be completed at an early date, and began the preparation of a union shelf list to be kept, with the union catalogue, in the Smithsonian Building. For this shelf list 27,417 cards were made, besides those prepared for the current publications catalogued. The cataloguing work of the year may be shown in detail by the following statistics:

| | |
|---|---|
| Volumes catalogued | 4,992 |
| Volumes recatalogued | 15 |
| Pamphlets catalogued | 2,622 |
| Charts catalogued | 289 |
| Typed cards added to catalogue | 8,716 |
| Library of Congress cards added to catalogue | 26,513 |

### SPECIAL ACTIVITIES

Some of the special activities of the year have already been recorded under the appropriate sections of this report. Those that have not been may be set down here. One detailed piece of work was the checking of several long sets of publications, with a view to completing them, especially those of the Carnegie Institution of Washington, the Zoological Society of London, and the United States Geological Survey. In connection with this work hundreds of paper-covered publications of the United States Geological Survey were listed for return to the survey, to be replaced by cloth-bound volumes, in accordance with a recent agreement between the Museum and the survey for the exchange of bound copies of their respective publications. The reports and other publications of the State geological surveys, which had been brought together the previous year from various Smithsonian libraries, were also checked and most of them used to fill gaps in either the main library of the Museum or the library in the department of geology. The 434 volumes not needed for this purpose were given to the United States Geological Survey. About 1,050 scientific reprints were distributed to the curators.

The Wistar Institute cards were filed to date, and more than 10,000 Concilium Bibliographicum cards of the author set were filed in the main library, while the assignment, begun the year before, of appropriate parts of the systematic set to the sectional libraries was continued. It is hoped that the rest of this set can soon be deposited in the sections interested, and that in the future the new increments as they are received can immediately be sorted and sent to the curators for their files. In preparation for the forthcoming Supplement to the Union List of Serials, the staff checked the periodical records of all the Smithsonian libraries, except the deposit in the Library of Congress, for new entries and for sets completed since 1925—a task which required a great deal of time. The work of organizing the scientific duplicates in the west stacks of the main building, which had been in progress for several years, was completed to the point where most of the material became available for use. The result was that before the end of the year hundreds of publications—many of which could not otherwise have been obtained except by purchase, and then often at fancy prices—were taken from the collection and assigned to the sets in which they were lacking. The rest will soon be used in the same way, or will be sent in exchange to other libraries.

In this connection it may be reported that 93 volumes and parts of the Bulletin of the Philosophical Society of Washington were sent to the society for use in completing its three sets. About 9,600 other duplicates not needed by the libraries of the Institution were distributed to Harvard University, Yale University, Chicago University, and the Marine Biological Laboratory at Woods Hole, for similar use, under an arrangement by which the Smithsonian is to receive an equivalent exchange, not merely of old material, but in the case of at least two of the universities, of new material issued by their presses. This happy arrangement will result in placing publications not required by the Institution in strategic positions elsewhere for the furthering of research and in conserving Smithsonian funds for the purchase of publications that can not be obtained by exchange.

The popular and semipopular material that had previously been brought together in a special building behind the Astrophysical Observatory and roughly grouped was more carefully arranged, pending final disposal. The set of star charts that the Smithsonian has been receiving for some years from various important observatories was transferred as a semipermanent loan to the United States Naval Observatory, and the Institution's set of Russian meteorological bulletins was likewise transferred to the United States Weather Bureau, the purpose in each case being to place the material where it would be of most aid to investigators.

It might be added that the librarian gave 14 lectures during the year, chiefly before local groups, including the Shakespeare Society. Several of these were on the Smithsonian Institution and its library system. He also contributed a chapter on the libraries of the Institution to the history of Washington, entitled "Washington—Past and Present," which has recently appeared.

### PHYSICAL CONDITION AND EQUIPMENT

About 400 feet of new steel shelving were installed in the main stack room of the Museum library. This additional space will relieve for the time being the congested condition of the library and will provide room for the rearranging of the collections that is soon to be undertaken. The improvement in physical equipment and appearance of several of the sectional libraries, notably those of botany and geology, should also be mentioned.

### CONCLUSION

On the whole, the system of libraries under the Smithsonian made considerable progress during the year toward becoming a complete and available reference instrument worthy of the Institution. This progress was retarded only by the lack of sufficient funds for binding, for the purchase of many of the books and periodicals requested by the curators—publications which could not be obtained by exchange—and for the employment of enough trained workers to enable the libraries not merely to meet the daily demands upon them, but to carry forward the work of reorganization that was begun a few years ago. It is gratifying to report, however, that this condition was somewhat relieved by the generous action of the Freer Gallery of Art, already mentioned, in allotting funds for use in connection with the cataloguing of its library; and that it will soon be further relieved, for on July 1, 1930, thanks to an increase in the Government appropriation to the Smithsonian for library purposes, $1,000 more than last year will be available for books and periodicals, and two new positions will be provided—namely, for a clerk in the exchange office of the library and a senior stenographer in the librarian's office.

But to make it possible for the system fully to meet the needs of the Institution, the annual sum for binding and for the purchase of publications should be further increased, and the staff should be further augmented by at least two cataloguers to revise the catalogue of the museum library and those of other units in the Smithsonian system, to expedite the making of the union catalogue, and to render available at the earliest possible moment the thousands of important publications still uncatalogued on the shelves; two

library assistants for service of a general nature in the sectional libraries; a library aid to relieve the more experienced assistants of minor library tasks that they are now obliged to perform in addition to their regular duties; and a stack attendant to keep the various collections in order, that publications may be found immediately when called for by the scientists. When this increased sum is at hand and these positions are provided and filled, the library system will be able to enter more worthily into the opportunity for service afforded by its close relation to the work of the Smithsonian Institution and its branches.

Respectfully submitted.

WILLIAM L. CORBIN,
*Librarian.*

Dr. CHARLES G. ABBOT,
*Secretary, Smithsonian Institution.*

# APPENDIX 11

## REPORT ON PUBLICATIONS

SIR: I have the honor to submit the following report on the publications of the Smithsonian Institution and the Government bureaus under its administrative charge during the year ending June 30, 1930:

The Institution proper published during the year 9 papers in the series of Smithsonian Miscellaneous Collections, 1 annual report and pamphlet copies of the 27 articles contained in the report appendix, and 1 special publication. The Bureau of American Ethnology published 5 bulletins and a list of publications of the bureau. The United States National Museum issued 1 annual report, 3 volumes of proceedings, 9 complete bulletins, 2 parts of bulletins, 1 volume and 3 parts in the series Contributions from the National Herbarium, and 32 separates from the proceedings.

Of these publications there were distributed during the year 168,163 copies, which included 71 volumes and separates of the Smithsonian Contributions to Knowledge, 19,575 volumes and separates of the Smithsonian Miscellaneous Collections, 29,886 volumes and separates of the Smithsonian annual reports, 4,598 Smithsonian special publications, 87,323 volumes and separates of the various series of the National Museum publications, 24,868 publications of the Bureau of American Ethnology, 49 publications of the National Gallery of Art, 24 volumes of the Annals of the Astrophysical Observatory, 82 reports of the Harriman Alaska Expedition, and 1,615 reports of the American Historical Association.

### SMITHSONIAN MISCELLANEOUS COLLECTIONS

Of the Smithsonian Miscellaneous Collections, volume 81, 2 papers and title page and table of contents were issued; volume 82, 7 papers, making 9 papers in all, as follows:

#### VOLUME 81

No. 14. Prehistoric Art of the Alaskan Eskimo. By Henry B. Collins, jr. November 14, 1929. 52 pp., 24 pls., 2 text figs. (Publ. 3023.)

No. 15. Arthropods as Intermediate Hosts of Helminths. By Maurice C. Hall. September 25, 1929. 77 pp. (Publ. 3024.)

Title page and table of contents. (Publ. 3063.)

VOLUME 82

No. 1. Absorption Lines of the Infra-Red Solar Spectrum. By C. G. Abbot and H. B. Freeman. August 31, 1929. 17 pp., 5 pls., 1 text fig. (Publ. 3026.)

No. 2. The Thoracic Mechanism of a Grasshopper, and its Antecedents. By R. E. Snodgrass. December 31, 1929. 111 pp., 54 text figs. (Publ. 3027.)

No. 3. The Radiation of the Planet Earth to Space. By C. G. Abbot. November 16, 1929. 12 pp., 2 pls., 1 text fig. (Publ. 3028.)

No. 4. The Characters of the Genus *Geocapromys* Chapman. By Gerrit S. Miller, jr. December 9, 1929. 3 pp., 1 pl. (Publ. 3029.)

No. 5. Mammals Eaten by Indians, Owls, and Spaniards in the Coast Region of the Dominican Republic. By Gerrit S. Miller, jr., December 11, 1929. 16 pp. 2 pls. (Publ. 3030.)

No. 6. The Past Climate of the North Polar Region. By Edward W. Berry. April 9, 1930. 29 pp., 4 text figs. (Publ. 3061.)

No. 7. The Atmosphere and the Sun. By H. Helm Clayton. 49 pp., 33 text figs. (Publ. 3062.)

SMITHSONIAN ANNUAL REPORTS

*Report for 1928.*—The complete volume of the Annual Report of the Board of Regents for 1928 was received from the Public Printer in November, 1929.

Annual Report of the Board of Regents of the Smithsonian Institution showing operations, expenditures, and condition of the Institution for the year ending June 30, 1928. xii+763 pp., 145 pls., 52 text figs. (Publ. 2981.)

The appendix contained the following papers:

The Wider Aspects of Cosmogony, by J. H. Jeans.

The Stars in Action, by Alfred H. Joy.

Island Galaxies, by A. Vibert Douglas.

Astronomical Telescopes, by F. G. Pease.

New Results on Cosmic Rays, by R. A. Millikan and G. H. Cameron.

Three Centuries of Natural Philosophy, by W. F. G. Swann.

The Hypothesis of Continental Displacement, by C. Schuchert.

On Continental Fragmentation and the Geologic Bearing of the Moon's Surficial Features, by Joseph Barrell.

The "Craters of the Moon" in Idaho, by H. T. Stearns.

The Oldest Known Petrified Forest, by W. Goldring.

Water Divining, by J. W. Gregory.

Some Problems of Polar Geography, by R. N. Rudmose Brown.

Birds of the Past in North America, by Alexander Wetmore.

Mammalogy and the Smithsonian Institution, by Gerrit S. Miller, jr.

The Controversy Over Human "Missing Links," by Gerrit S. Miller, jr.

What is known of the Migrations of Some of the Whalebone Whales, by Remington Kellogg.

Ecology of the Red Squirrel, by A. Brooker Klugh.

Adventures of a Naturalist in the Ceylon Jungle, by Casey A. Wood.

Communication Among Insects, by N. E. McIndoo.

Our Insect Instrumentalists and Their Musical Technique, by H. A. Allard.

The Neanderthal Phase of Man, by Aleš Hrdlička.

Indian Costumes in the United States National Museum, by H. W. Krieger.

Mounds and Other Ancient Earthworks of the United States, by David I. Bushnell, jr.

Geochronology, by Grand de Geer.

The Physiology of the Ductless Glands, by N. B. Taylor.

Arrhenius Memorial Lecture, by Sir James Walker.

Theodore William Richards, by Gregory P. Baxter.

*Report for 1929.*—The report of the executive committee and proceedings of the Board of Regents of the Institution and the report of the secretary, both forming parts of the annual report of the Board of Regents to Congress, were issued in December, 1929.

Report of the executive committee and proceedings of the Board of Regents of the Smithsonian Institution for the year ending June 30, 1929. 12 pp. (Publ. 3032.)

Report of the Secretary of the Smithsonian Institution for the year ending June 30, 1929. 144 pp., 2 text figs. (Publ. 3031.)

The general appendix to this report, which was in press at the close of the year, contains the following papers:

The Physics of the Universe, by Sir James Jeans.

Counting the Stars and some Conclusions, by Frederick H. Seares.

The Lingering Dryad, by Paul R. Heyl.

What is Light? by Arthur H. Compton.

Artificial Cold, by Gordon B. Wilkes.

Photosynthesis, by E. C. C. Baly.

Newly Discovered Chemical Elements, by N. M. Bligh.

Synthetic Perfumes, by H. Stanley Redgrove.

X Raying the Earth, by Reginald A. Daly.

Extinction and Extermination, by I. P. Tolmachoff.

The Gulf Stream and its Problems, by H. A. Marmer.

The Mystery of Life, by F. G. Donnan.

The Transition from Live to Dead: the Nature of Filtrable Viruses, by A. E. Boycott.

Heritable Variations, their Production by X rays, and their Relation to Evolution, by H. J. Muller.

Social Parasitism in Birds, by Herbert Friedmann.

How Insects Fly, by R. E. Snodgrass.

Climate and Migrations, by J. C. Curry.

Ur of the Chaldees: More Royal Tombs, by C. Leonard Woolley.

The Population of Ancient America, by H. J. Spinden.

The Aborigines of the Ancient Island of Hispaniola, by Herbert W. Krieger.

The Beginning of the Mechanical Transport Age in America, by Carl W. Mitman.

The Servant in the House; a Brief History of the Sewing Machine, by Frederick L. Lewton.

Thomas Chrowder Chamberlin (1843–1928), by Bailey Willis.

Hideyo Noguchi, by Simon Flexner.

SPECIAL PUBLICATIONS

Explorations and Field Work of the Smithsonian Institution in 1929. 222 pp., 200 text figs. (Publ. 3060.)

## PUBLICATIONS OF THE UNITED STATES NATIONAL MUSEUM

The editorial work of the National Museum is in the hands of Dr. Marcus Benjamin. During the year ending June 30, 1930, the Museum published 1 annual report, 3 volumes of proceedings, 9 complete bulletins, 2 parts of bulletins, 1 complete volume and 3 parts in the series Contributions from the United States National Herbarium, and 32 separates from the proceedings.

The issues of the bulletin were as follows:

Bulletin 76. Asteroidea of the North Pacific and Ajacent Waters. Part 3. Forcipulata (concluded). By Walter Kenrick Fisher.

Bulletin 100. Contributions to the Biology of the Philippine Archipelago and Adjacent Regions.

Volume 9. Bryozoa of the Philippine Region. By Ferdinand Canu and Ray S. Bassler.

Volume 10. The Fishes of the Families Amiidae, Chandidae, Duleidae, and Serranidae, Obtained by the United States Bureau of Fisheries Steamer "Albatross" in 1907 to 1910, Chiefly in the Philippine Islands and Adjacent Seas. By Henry W. Fowler and Barton A. Bean.

Bulletin 104. The Foraminifera of the Atlantic Ocean.

Part 7. Nonionidae, Camerinidae, Peneroplidae, and Alveolinellidae. By Joseph Augustine Cushman.

Bulletin 147. Archeological and Historical Investigations in Samana, Dominican Republic. By Herbert W. Krieger.

Bulletin 148. Collections of Objects of Religious Ceremonial in the United States National Museum. By Immanuel Moses Casanowicz.

Bulletin 149. Composition and Structure of Meteorites. By George P. Merrill.

Bulletin 150. Revision of the Fishes of the Family Liparidae. By Victor Burke.

Bulletin 151. East African Reptiles and Amphibians in the United States National Museum. By Arthur Loveridge.

Bulletin 152. The Cancroid Crabs of America of the Families Euryalidae, Portunidae, Atelecyclidae, Cancridae and Xanthidae. By Mary J. Rathbun.

Bulletin 153. Birds Collected by the Childs Frick Expedition to Ethiopia and Kenya Colony. Part 1. Non-Passeres. By Herbert Friedmann.

The issues of the contributions from the United States National Herbarium were as follows:

Volume 22. Systematic Plant Studies—Chiefly Tropical American.

Volume 24, Part 9. The Grasses of Central America. By A. S. Hitchcock.

Volume 26, Part 4. The Piperaceae of Costa Rica. By William Trelease.

Part 5. Notes on Certain Type Specimens of American Asteraceae in European Herbaria. By S. F. Blake.

Of the separates from the proceedings, 1 was from volume 75, 22 from volume 76, and 9 from volume 77.

## PUBLICATIONS OF THE BUREAU OF AMERICAN ETHNOLOGY

The editorial work of the bureau has continued under the direction of the editor, Mr. Stanley Searles. During the year, five bulletins and a list of publications were issued, as follows:

Bulletin 88. Myths and Tales of the Southeastern Indians (Swanton). x+275 pp.

Bulletin 90. Papago Music (Densmore). xx+229 pp., 19 pls., 4 figs.

Bulletin 91. Additional Studies of the Arts, Crafts, and Customs of the Guiana Indians (Roth). xvii+110 pp., 34 pls., 90 figs.

Bulletin 93. Pawnee Music (Densmore). xvii+129 pp., 8 pls.

Bulletin 95. Contributions to Fox Ethnology.—II (Michelson). vii+183 pp., 1 fig.

List of Publications of the Bureau of American Ethnology. 50 pp.

Publications in press are as follows:

Forty-fifth Annual Report. Accompanying papers: The Salishan Tribes of the Western Plateaus (Teit, edited by Boas); Tattooing and Face and Body Painting of the Thompson Indians, British Columbia (Teit, edited by Boas); The Ethnobotany of the Thompson Indians of British Columbia (Steedman); The Osage Tribe: Rite of the Wa-xo-be (La Flesche).

Forty-sixth Annual Report. Accompanying papers: Anthropological Survey in Alaska (Hrdlička); Report to the Honorable Isaac S. Stevens, Governor of Washington Territory, on the Indian Tribes of the Upper Missouri (Denig, edited by Hewitt).

Bulletin 94. Tobacco among the Karuk Indians of California (Harrington).

Bulletin 96. Early Pueblo Ruins in the Piedra District, Southwestern Colorado (Roberts).

## REPORT OF THE AMERICAN HISTORICAL ASSOCIATION

The annual reports of the American Historical Association are transmitted by the association to the Secretary of the Smithsonian Institution and are communicated by him to Congress, as provided by the act of incorporation of the association.

The annual reports for 1925 and 1926 and the supplemental volumes to these reports were issued during the year. The annual reports for 1927 and 1928 (1 volume) and for 1929 were in press at the close of the year, and also the supplemental volume to the report for 1927.

## REPORT OF THE NATIONAL SOCIETY, DAUGHTERS OF THE AMERICAN REVOLUTION

The manuscript of the Thirty-second Annual Report of the National Society, Daughters of the American Revolution, was transmitted to Congress, in accordance with the law, December 9, 1929.

### ALLOTMENTS FOR PRINTING

The congressional allotments for the printing of the Smithsonian Report to Congress and the various publications of the Government bureaus under the administration of the Institution were virtually used up at the close of the year. The appropriation for the coming year ending June 30, 1931, totals $99,000, allotted as follows:

| | |
|---|---|
| Annual report to the Congress of the Board of Regents of the Smithsonian Institution | $11,500 |
| National Museum | 46,500 |
| Bureau of American Ethnology | 28,300 |
| National Gallery of Art | 500 |
| International Exchanges | 300 |
| International Catalogue of Scientific Literature | 100 |
| National Zoological Park | 300 |
| Astrophysical Observatory | 4,500 |
| Annual report of the American Historical Association | 7,000 |

### SMITHSONIAN ADVISORY COMMITTEE ON PRINTING AND PUBLICATION

The editor has continued to serve as secretary of the Smithsonian advisory committee on printing and publication, to which are referred for consideration and recommendation all manuscripts offered to the Institution and its branches. The committee also considers matters of publication policy. Five meetings were held during the year and 70 manuscripts acted upon. The membership at the close of the year was as follows: Dr. Leonhard Stejneger, head curator of biology, National Museum, chairman; Dr. William M. Mann, director, National Zoological Park; Mr. M. W. Stirling, chief, Bureau of American Ethnology; Dr. R. S. Bassler, head curator of geology, National Museum; Mr. W. P. True, editor of the Institution, secretary; Dr. Marcus Benjamin, editor of the National Museum; and Mr. Stanley Searles, editor of the Bureau of American Ethnology.

Respectfully submitted.

W. P. True, *Editor.*

Dr. Charles G. Abbot,
*Secretary, Smithsonian Institution.*

# APPENDIX 12

## LIST OF SUBSCRIBERS TO THE JAMES SMITHSON MEMORIAL EDITION, SMITHSONIAN SCIENTIFIC SERIES, SINCE NOVEMBER 15, 1929 [1]

Mr. Frank C. Ball,
Muncie, Ind.
Mrs. John N. Carey,
Indianapolis, Ind.
Mr. Frederic G. Carnochan,
New York City.
Mr. M. Friedsam,
New York City.
Mr. John Gellatly,
New York City.
Mr. William Hale Harkness,
New York City.
Mrs. William L. Harkness,
New York City.
Mrs. Edward Henry Harriman,
New York City.
Mr. T. A. Havemeyer,
New York City.
Mr. Franklyn L. Hutton,
New York City.
Mrs. Amelia L. Lashar,
Fairfield, Conn.
Mr. C. R. Morley,
Cleveland, Ohio.
Dr. Fred T. Murphy,
Detroit, Mich.
Mr. Philip M. Plant,
New York City.
Mr. Charles L. Riker,
New York City.
Mrs. Mary E. Sage,
West Hartford, Conn.
Countess László Széchenyi,
Washington, D. C.
Mr. W. H. Truesdale,
New York City.
Mr. Charles B. Van Duzen,
Detroit, Mich.

[1] For full list of subscribers see report of the Secretary of the Smithsonian Institution for the year ending June 30, 1929.

# REPORT OF THE EXECUTIVE COMMITTEE OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION FOR THE YEAR ENDED JUNE 30, 1930

*To the Board of Regents of the Smithsonian Institution:*

Your executive committee respectfully submits the following report in relation to the funds of the Smithsonian Institution together with a statement of the appropriations by Congress for the Government bureaus in the administrative charge of the Institution.

## SMITHSONIAN ENDOWMENT FUND

| | | |
|---|---|---|
| The original bequest of James Smithson was £104,960 8 shillings 6 pence—$508,318.46. Refunds of money expended in prosecution of the claim, freights, insurance, etc., together with payment into the fund of the sum of £5,015 which had been withheld during the lifetime of Madame de la Batut, brought the fund to the amount of | | $550,000.00 |
| Since the original bequest the Institution has received gifts from various sources, chiefly in the years prior to 1893, the income from which may be used for the general work of the Institution to the amount of | | 260,602.39 |
| Total capital gain from investment of savings from income | | 207,796.11 |
| Total capital gain from sale of securities, stock dividends, etc | | 15,391.35 |
| Total endowment for general purposes as per last report | $1,022,385.75 | |
| Capital gain from gifts during year ended June 30, 1930 | 1,418.00 | |
| Capital gain from stock dividends, sale of securities, etc | 828.57 | |
| Capital gain from sale of Smithsonian Scientific Series [1] | 9,157.53 | |
| Present total endowment for general purposes | 1,033,789.85 | 1,033,789.85 |

[1] Approximately $7,000 income from sales of Smithsonian Scientific Series not yet invested will appear in next report.

The Institution holds also a number of endowment gifts the income of each being restricted to specific use. These are invested and stand on the books of the Institution as follows:

| | | |
|---|---|---|
| Bacon, Virginia Purdy, fund, for a traveling scholarship to investigate fauna of countries other than the United States | | $65,812.09 |
| Baird, Lucy H., fund, for creating a memorial to Secretary Baird | | 2,076.68 |
| Canfield collection fund, for increase and care of the Canfield collection of minerals | | 50,242.50 |
| Casey, Thomas L., fund for maintenance of Casey collection and promotion of researches relating to Coleoptera | | 6,416.97 |
| Chamberlain, Frances Lea, fund, for increase and promotion of Isaac Lea collection of gems and mollusks | | 36,990.04 |
| Hodgkins fund, specific, for increase and diffusion of more exact knowledge in regard to nature and properties of atmospheric air | | 100,000.00 |
| Hughes, Bruce, fund, to found Hughes alcove | | 17,942.72 |
| Myer, Catherine Walden, fund, for purchase of first-class works of art for the use of and benefit of the National Gallery of Art | | 21,700.97 |
| Pell, Cornelia Livingston, fund, for maintenance of Alfred Duane Pell collection | | 3,171.41 |
| Poore, Lucy T. and George W., fund, for general use of the Institution when principal amounts to the sum of $250,000 | | 58,148.61 |
| Reid, Addison T., fund, for founding chair in biology in memory of Asher Tunis | | 23,476.50 |
| Roebling fund, for care, improvement, and increase of Roebling collection of minerals | | 158,524.06 |
| Springer, Frank, fund, for care, etc., of Springer collection and library | | 30,000.00 |
| Walcott, Charles D. and Mary Vaux, research fund, for development of geological and paleontological studies and publishing results thereof | | 12,477.50 |
| Younger, Helen Walcott, fund, held in trust | | 49,812.50 |
| Total endowment for specific purposes other than Freer endowment as per last report | $626,003.70 | |
| Capital gain from investment of savings from income during year ended June 30, 1930 | 8,825.19 | |
| Capital gain from stock dividends, sale of securities, etc., during year ended June 30, 1930 | 1,963.66 | |
| Excluding Freer endowment, total present endowment for specific purposes | 636,792.55 | 636,792.55 |

FREER GALLERY OF ART FUND

Early in 1906, by deed of gift, Mr. Charles L. Freer, of Detroit, gave to the Institution his collection of Chinese and other oriental objects of art, as well as paintings, etchings, and other works of art by Whistler, Thayer, Dewing, and other artists. Later he also gave funds for the construction of a building to house the collection, and finally in

his will, probated November 6, 1919, he provided stock and securities to the estimated value of $1,958,591.42 as an endowment fund for the operation of the gallery. In view of the importance and special nature of the gift and the requirements of the testator in respect to it, all Freer funds are kept separate from the other funds of the Institution, and the accounting in respect to them is stated separately.

| | | |
|---|---|---|
| Original endowment for expenses of gallery | | $1, 958, 591. 42 |
| Total capital gain from investment of savings from income | | 410, 381. 31 |
| Total capital gain from stock dividends, sale, etc., of securities | | 2, 931, 956. 77 |
| Total capital as per last report | $5, 236, 054. 02 | |
| Capital gain from investment of savings from income during year ended June 30, 1930 | 11, 602. 60 | |
| Capital gain from stock dividends, sale of securities, etc., during year ended June 30, 1930 | 53, 272. 88 | |
| Total Freer endowment for specific purposes | 5, 300, 929. 50 | 5, 300, 929. 50 |

SUMMARY

| | |
|---|---|
| Invested endowment for general purposes | 1, 033, 789. 85 |
| Invested endowment for specific purposes other than Freer endowment | 636, 792. 55 |
| Total invested endowment other than Freer endowment | 1, 670, 582. 40 |
| Freer invested endowment for specific purposes | 5, 300, 929. 50 |
| Total invested endowment for all purposes | 6, 971, 511. 90 |

CLASSIFICATION OF INVESTMENTS

| | | |
|---|---|---|
| Deposited in the United States Treasury at 6 per cent per annum as authorized in the United States Revised Statutes, section 5591 | | 1, 000, 000. 00 |
| Investments other than Freer endowment: | | |
| Bonds | $252, 024. 65 | |
| Stocks | 403, 100. 20 | |
| Real estate first-mortgage notes | 15, 000. 00 | |
| Uninvested capital | 457. 55 | |
| | | 670, 582. 40 |
| Total investments other than Freer endowment | | 1, 670, 582. 40 |
| Investments of Freer endowment: | | |
| Bonds | $2, 814, 767. 12 | |
| Stocks | 2, 407, 664. 50 | |
| Real estate first-mortgage notes | 76, 500. 00 | |
| Uninvested capital | 1, 997. 88 | |
| | | 5, 300, 929. 50 |
| Total investments | | 6, 971, 511. 90 |

## INCOME FROM INVESTMENTS DURING YEAR ENDED JUNE 30, 1930

| | | Corresponding figures for year ending June 30, 1929 |
|---|---|---|
| From $1,000,000 deposited in United States Treasury at 6 per cent | $60,000.00 | $60,000.00 |
| From $670,582.40 invested in stocks, bonds, etc., other than Freer endowment at about 5.16 per cent | [1] 34,624.40 | 30,582.77 |
| Total income other than Freer endowment | 94,624.40 | 90,582.77 |
| **FREER ENDOWMENT** | | |
| From $5,300,929.50 invested in stocks, bonds, etc., at about 6.32 per cent | [2] 334,936.39 | 282,435.13 |
| Total income from investments | 429,560.79 | 373,017.90 |

## CASH BALANCES, RECEIPTS AND DISBURSEMENTS DURING THE FISCAL YEAR [3]

| | | |
|---|---|---|
| Cash balance on hand June 30, 1929 | | $216,994.28 |
| **RECEIPTS** | | |
| Cash from invested endowments and from miscellaneous sources for general use of the Institution | $74,850.62 | |
| Cash for increase of endowments for specific use | 1,039.57 | |
| Cash gifts for increase of endowments for general use | 189.10 | |
| Cash gifts, etc., for specific use (not to be invested) | 105,710.88 | |
| Cash received as royalties from sales of Smithsonian Scientific Series [4] | 21,833.92 | |
| Cash gain from sale of securities, etc. (to be invested) | 2,170.13 | |
| Cash income from endowments for specific use other than Freer endowment, and from miscellaneous sources | 72,078.30 | |
| Cash capital from sale, call of securities, etc. (to be reinvested) | 175,357.85 | |
| Total receipts other than Freer endowment | | 453,220.37 |

[1] In addition to this income the sum of $3,703.13 was received from gain from sale of securities and stock dividends.

[2] In addition to this income the sum of $53,310.34 was received from gain from sale of securities and stock dividends

[3] This statement does not include Government appropriations under the administrative charge of the Institution.

[4] Under resolution of the Board of Regents, three-fourths of this income is credited to the permanent endowment fund of the Institution and one-fourth is made expendable for general purposes.

| | | |
|---|---|---|
| Cash receipts from Freer endowment: | | |
| Income from investments | $303, 780. 87 | |
| Net gain from sale of securities, etc. (to be invested) | 38, 480. 34 | |
| Cash capital from sale, call of securities, etc. (to be reinvested) | 1, 432, 644. 95 | |
| | | $1, 774, 906. 16 |
| Total | | 2, 445, 120. 81 |

DISBURSEMENTS

| | | |
|---|---|---|
| From funds for general work of the Institution: | | |
| Buildings—care, repair, and alteration | $1, 937. 05 | |
| Furniture and fixtures | 529. 17 | |
| General administration [5] | 24, 154. 26 | |
| Library | 3, 170. 37 | |
| Publications (comprising preparation, printing, and distribution) | 13, 224. 93 | |
| Researches and explorations | 19, 294. 39 | |
| International exchanges | 4, 830. 35 | |
| | | 67, 140. 52 |
| From funds for specific use other than Freer endowment: | | |
| Investments made from gifts, from gain from sales of securities, etc., and from saving on income | 20, 659. 95 | |
| Other expenditures, consisting largely of research work, travel, increase and care of special collections, etc., from income of endowment funds and cash gifts for specific use | 147, 063. 31 | |
| Cash capital from sale, call of securities, etc., reinvested | 174, 900. 30 | |
| | | 342, 623. 56 |
| From Freer endowment: | | |
| Operating expenses of gallery, salaries, purchases of art objects, field expenses, etc | 337, 207. 13 | |
| Investments made from gain from sale of securities, etc., and from income | 50, 045. 48 | |
| Cash capital from sale, call of securities, etc., reinvested | 1, 433, 233. 95 | |
| | | 1, 820, 486. 56 |
| Balance on hand June 30, 1930 | | 214, 870. 17 |
| Total | | 2, 445, 120. 81 |

[5] This includes salaries of the secretary and certain others.

## EXPENDITURES FOR RESEARCHES IN PURE SCIENCE, EXPLORATIONS, CARE, INCREASE AND STUDY OF COLLECTIONS, ETC.

| | | |
|---|---|---|
| Expenditures from general endowment: | | |
| Publications | $13,224.93 | |
| Researches and explorations | 19,294.39 | |
| | | $32,519.32 |
| Expenditures from funds devoted to specific purposes: | | |
| Researches and explorations | 69,355.97 | |
| Care, increase and study of special collections | 16,168.41 | |
| Publications | 27,712.45 | |
| | | 113,236.83 |
| Total | | 145,756.15 |

*Table showing growth of endowment funds of the Smithsonian Institution*

| Year | Endowment for general work of the Institution being original Smithson bequest, gifts from other sources, and invested savings of income | Endowment for specific researches, etc., including invested savings of income | Freer gift for construction of Freer Gallery of Art building | Freer bequest for operation of Freer Gallery of Art, including salaries, care, etc. |
|---|---|---|---|---|
| 1846–1891 | [1] $702,000.00 | | | |
| 1892 | 802,000.00 | $101,000.00 | | |
| 1893–1894 | 852,000.00 | 101,000.00 | | |
| 1895–1903 | 877,000.00 | 102,000.00 | | |
| 1904–1913 | 885,807.58 | 111,692.42 | | |
| 1914 | 885,807.58 | 116,692.42 | | |
| 1915 | 886,084.02 | 143,515.98 | | |
| 1916 | 887,607.08 | 160,527.30 | $1,000,000.00 | |
| 1917 | 887,830.00 | 164,304.38 | | |
| 1918 | [2] 883,867.00 | 176,157.38 | | |
| 1919 | 884,305.00 | 190,489.38 | | |
| 1920 | 884,747.00 | 198,149.02 | | |
| 1921 | 884,933.74 | 272,538.31 | [3] 367,072.04 | $1,253,004.75 |
| 1922 | 886,107.14 | 291,858.14 | | 1,842,144.75 |
| 1923 | 886,246.14 | 306,524.14 | | [4] 3,296,574.75 |
| 1924 | 886,373.31 | 319,973.19 | | 3,401,355.42 |
| 1925 | 886,769.73 | 338,136.77 | | 3,459,705.34 |
| 1926 | 886,830.13 | 342,876.37 | | 3,714,361.23 |
| 1927 | 886,877.79 | 498,401.96 | | 4,171,880.61 |
| 1928 | 929,068.21 | 665,233.29 | | 4,268,244.26 |
| 1929 | [5] 1,022,385.75 | 626,003.70 | | 5,236,054.02 |
| 1930 | 1,033,789.85 | 636,792.55 | | 5,300,929.50 |

[1] Original endowment plus income from savings during these years.
[2] Loss on account of bonds reduced on books from par to market value.
[3] Cash from sale of 2,000 shares of Parke, Davis & Co. stock, including dividends, and interest on gift of $1,000,000.
[4] In this year Parke, Davis & Co. declared 100 per cent stock dividend.
[5] Increase largely from funds transferred from specific endowment column and income released for general work of the Institution.

## BALANCE SHEET OF THE SMITHSONIAN INSTITUTION, JUNE 30, 1930

### ASSETS

| | | |
|---|---|---|
| Stocks and bonds at acquirement value: | | |
| Consolidated fund | $578, 292. 40 | |
| Freer bequest | 5, 300, 929. 50 | |
| Springer fund | 30, 000. 00 | |
| Walcott fund | 12, 477. 50 | |
| Younger fund | 49, 812. 50 | |
| | | $5, 971, 511. 90 |
| U. S. Treasury Department deposit | | 1, 000, 000. 00 |
| Miscellaneous, principally funds advanced for printing publications and field expenses (to be repaid) | | 33, 417. 47 |
| Cash: | | |
| Funds in U. S. Treasury and in banks | $214, 870. 17 | |
| In office safe for cash transactions | 1, 300. 00 | |
| | | 216, 170. 17 |
| Total | | 7, 221, 099. 54 |

### LIABILITIES

| | | |
|---|---|---|
| Freer bequest, capital accounts: | | |
| Court and grounds fund | 592, 046. 60 | |
| Court and grounds maintenance fund | 149, 608. 46 | |
| Curator fund | 602, 395. 38 | |
| Residuary estate fund | 3, 956, 879. 06 | |
| | | 5, 300, 929. 50 |
| Bacon fund capital | | 65, 812. 09 |
| Baird fund capital | | 2, 076. 68 |
| Canfield collection fund, capital | | 50, 242. 50 |
| Casey, Thomas L., fund, capital | | 6, 416. 97 |
| Chamberlain fund, capital | | 36, 990. 04 |
| Hodgkins fund, specific | | 100, 000. 00 |
| Hughes, Bruce, fund, capital | | 17, 942. 72 |
| Myer fund, capital | | 21, 700. 97 |
| Pell fund, capital | | 3, 171. 41 |
| Poore fund, capital | | 58, 148. 61 |
| Reid fund, capital | | 23, 476. 50 |
| Roebling fund, capital | | 158, 524. 06 |
| Smithsonian unrestricted fund, capital | | 1, 033, 789. 85 |
| Springer fund, capital | | 30, 000. 00 |
| Walcott research fund, capital | | 12, 477. 50 |
| Younger fund, capital | | 49, 812. 50 |

| | | |
|---|---|---|
| Freer bequest, current accounts: | | |
| Court and grounds fund | $20,213.69 | |
| Court and grounds maintenance fund | 5,629.15 | |
| Curator fund | 14,971.67 | |
| Residuary estate fund | 66,830.47 | |
| | | $107,644.98 |
| Springer fund, current account | | 394.21 |
| Walcott fund, current account | | 1,140.42 |
| Younger fund, current account | | 217.50 |
| Miscellaneous accounts held by the Institution for the most part for specific use | | 140,190.53 |
| Total | | 7,221,099.54 |

All payments are made by check, signed by the secretary of the Institution, on the Treasurer of the United States, and all revenues are deposited to the credit of the same account. In many instances deposits are placed in bank for convenience of collection and later are withdrawn in round amounts and deposited in the Treasury.

The practice of investing temporarily idle funds in time deposits has proven satisfactory. During the year the interest derived from this source has resulted in a total of $8,103.31.

The foregoing report relates only to the private funds of the Smithsonian Institution. The following is a statement of the congressional appropriations for the past 10 years, for the support of the several governmental branches under the administrative control of the Institution, and of appropriations for other special purposes during that period.

*Table showing the appropriations made by Congress during the last 10 years, intrusted to the care of the Smithsonian Institution*

| Year | International Exchanges | American Ethnology | Cooperative ethnological researches | International Catalogue of Scientific Literature | Astrophysical Observatory | Increase of compensation | National Museum | Gellatly art collection |
|---|---|---|---|---|---|---|---|---|
| 1921 | $50,000.00 | $44,000.00 | | $7,500.00 | $13,000.00 | | $419,120.00 | |
| 1922 | 50,000.00 | 46,000.00 | | 7,500.00 | 15,500.00 | | 419,138.86 | |
| 1923 | 45,000.00 | 44,000.00 | | 7,500.00 | 15,500.00 | $109,044.00 | 418,120.00 | |
| 1924 | 43,000.00 | 44,000.00 | | 7,500.00 | 15,500.00 | 112,704.00 | 415,000.00 | |
| 1925 | 49,550.00 | 57,160.00 | | 8,861.66 | 21,580.00 | | 547,292.00 | |
| 1926 | 46,260.00 | 57,160.00 | | 8,000.00 | [1] 31,180.00 | | 554,392.00 | |
| 1927 | 46,260.00 | 57,160.00 | | 7,500.00 | 31,180.00 | | 565,820.00 | |
| 1928 | 46,855.00 | 58,720.00 | | 7,260.00 | 32,060.00 | | 606,960.00 | |
| 1929 | 50,355.00 | 65,800.00 | $20,000.00 | 7,885.00 | 36,630.00 | | 701,524.00 | |
| 1930[2] | 51,297.00 | 68,800.00 | | 7,885.00 | 36,720.00 | | 717,014.00 | $21,000.00 |

| Year | Safeguarding dome of Natural History Building | National Zoological Park | Additional for Zoological Park | National Gallery of Art | Printing and binding | Additional Assistant Secretary | Salaries and expenses | Additional fire protection |
|---|---|---|---|---|---|---|---|---|
| 1921 | | $125,000.00 | | $15,000.00 | | | | |
| 1922 | | 125,000.00 | [3] $80,000.00 | 15,000.00 | | | | |
| 1923 | | 125,000.00 | [3] 2,500.00 | 15,000.00 | $77,400.00 | | | |
| 1924 | | 125,000.00 | | 16,000.00 | 77,400.00 | | | |
| 1925 | | 151,487.00 | | 20,158.00 | 90,000.00 | $6,000.00 | | $8,500.00 |
| 1926 | | 157,000.00 | | 21,028.00 | 90,000.00 | 6,000.00 | | |
| 1927 | | 173,199.00 | | 29,381.00 | 90,000.00 | 6,000.00 | | |
| 1928 | | 175,000.00 | [4] 25,000.00 | 30,356.00 | 90,000.00 | [5] 7,500.00 | | |
| 1929 | [6] $80,000.00 | 195,550.00 | [4] 30,000.00 | 35,273.00 | 95,000.00 | | $35,804.00 | |
| 1930 | | 203,000.00 | [7] 222,000.00 | 34,853.00 | 95,000.00 | | 36,004.00 | |

[1] Increase in appropriation due to Government assuming part of the expenses of the Chilean station, which up to this time had been supported by private funds of the Smithsonian Institution.
[2] Increases over former figures due to passage of Welch Act after printing of last report.
[3] Additional land.
[4] Building for birds.
[5] After 1928 this item is included in appropriation for salaries and expenses.
[6] Work done by Supervising Architect and funds disbursed by United States Treasury.
[7] Building for reptiles, etc., $220,000; gates for south boundary of park, $2,000.

The report of the audit of the Smithsonian private funds is printed below.

SEPTEMBER 23, 1930.

EXECUTIVE COMMITTEE, BOARD OF REGENTS,
*Smithsonian Institution, Washington, D. C.*

SIRS: Pursuant to agreement we have audited the accounts of the Smithsonian Institution for the fiscal year ended June 30, 1930, and certify the balance of cash on hand June 30, 1930, to be $216,170.17.

We have verified the record of receipts and disbursements maintained by the Institution and the agreement of the book balances with the bank balances.

We have examined all the securities in the custody of the Institution and in the custody of the banks and found them to agree with the book records.

We have compared the stated income of such securities with the receipts of record and found them in agreement therewith.

We have examined all vouchers covering disbursements for account of the Institution during the fiscal year ended June 30, 1930, together with the authority therefor and have compared them with the Institution's record of expenditures and found them to agree.

We have examined and verified the accounts of the Institution with each trust fund.

We found the books of account and records well and accurately kept and the securities conveniently filed and securely cared for.

All information requested by your auditors was promptly and courteously furnished.

We certify the balance sheet in our opinion correctly presents the financial condition of the Institution as at June 30, 1930.

CAPITAL AUDIT COMPANY,
WILLIAM L. YAEGER,
*Certified Public Accountant.*

Respectfully submitted.

FREDERIC A. DELANO,
R. WALTON MOORE,
J. C. MERRIAM,
*Executive Committee.*

# PROCEEDINGS OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION FOR THE FISCAL YEAR ENDED JUNE 30, 1930

## ANNUAL MEETING, DECEMBER 12, 1929

Present: Chief Justice W. H. Taft, chancellor, in the chair, Senator Joseph T. Robinson, Senator Claude A. Swanson, Representative R. Walton Moore, Representative Robert Luce, Mr. Frederic A. Delano, Mr. Dwight W. Morrow, Mr. Charles E. Hughes, Dr. John C. Merriam, and the secretary, Dr. C. G. Abbot. Dr. Alexander Wetmore, assistant secretary, was also present.

The secretary announced that Representative Walter H. Newton had resigned his seat as a Member of the House on June 30, last, thus automatically terminating his appointment as a regent, and that the Speaker had appointed Representative Robert Luce as a regent to succeed him.

Mr. Delano, chairman of the executive committee, submitted the following customary resolution, which was adopted:

*Resolved*, That the income of the Institution for the fiscal year ending June 30, 1931, be appropriated for the service of the Institution, to be expended by the secretary, with the advice of the executive committee, with full discretion on the part of the secretary as to items.

The secretary stated that his report for the fiscal year ending June 30, 1929, had been supplied to the regents, and called attention to the many interesting and encouraging events of the year.

At the request of the secretary, Doctor Wetmore explained the proposed building program for the Institution. After full discussion, the following resolution was adopted:

*Resolved*, That the permanent committee be authorized to formulate a program to be presented to the Bureau of the Budget, and subsequently transmitted to Congress, comprehending the proposed additional buildings needed by the Smithsonian Institution.

The secretary stated that the Smithsonian Scientific Series was meeting with gratifying success and that the Institution had already received from this source royalties amounting to about $28,000, which would increase as time passed. He reminded the board that Ambassador Charles G. Dawes had made a grant for the purpose of conducting historical studies in European archives and that Dr. Charles Upson Clark, an expert, was now engaged in the work and had already met with success in his researches.

The annual report of the National Gallery of Art Commission was presented. The report was accepted, and the board adopted the following resolution:

*Resolved*, That the Board of Regents of the Smithsonian Institution hereby approves the recommendation of the National Gallery of Art Commission that W. K. Bixby, W. H. Holmes, Herbert L. Pratt, and Charles Borie, be reelected as members of the commission for the ensuing term of four years, their present terms having expired.

The annual report of the executive committee was presented and accepted.

The annual report of the permanent committee was submitted. This included a suggestion for the establishment of a department for the arousing of public interest in the Institution and for increasing its endowment, which was referred to the permanent committee with power to act.

The matter of the awarding of the Langley medal was next brought up, and the following two resolutions were adopted:

*Resolved*, That in view of the service rendered to aviation by his pioneer contributions to the development of the airplane engine, the Board of Regents of the Smithsonian Institution hereby posthumously awards the Langley gold medal for aerodromics to the late Charles Matthews Manly.

*Resolved*, That the Board of Regents of the Smithsonian Institution award the Langley gold medal for aerodromics to Commander Richard Evelyn Byrd, United States Navy, for his pioneer flights over the North and South Poles of the earth, his nonstop flight over the Atlantic Ocean, and the scientific discoveries associated with these flights.

### MEETING OF FEBRUARY 13, 1930

Present: Vice President Charles Curtis, Senator Reed Smoot, Senator Claude A. Swanson, Representative R. Walton Moore, Representative Robert Luce, Mr. Frederic A. Delano, and the secretary, Dr. C. G. Abbot. Dr. Alexander Wetmore, assistant secretary, was also present.

The secretary announced the resignation of the Hon. William Howard Taft as Chief Justice of the United States, stating that this action automatically terminated his service as a regent and consequently as chancellor of the Institution. The following resolutions were then adopted:

*Resolved*, That the Board of Regents of the Smithsonian Institution has learned with deep regret of the illness and consequent resignation of its chancellor, the Hon. William Howard Taft, from the office of Chief Justice of the United States, thereby automatically severing his connection with this Board;

*Resolved*, That the board hereby expresses its deep sense of the great service rendered by Mr. Taft to the Smithsonian Institution, and of the loss in counsel and in association which his departure entails;

*Resolved*, That a copy of these resolutions be communicated to Mr. Taft.

The secretary further stated that on December 19, 1929, the Speaker of the House had reappointed as regents Representatives Albert Johnson, R. Walton Moore, and Robert Luce.

The secretary recalled to the regents that at the last annual meeting their attention had been drawn to the building program of the Institution, the most urgent item of which was the addition of wings to the present Natural History Building at an estimated cost of $6,500,000, and Doctor Wetmore exhibited blue prints of the proposed additions.

The secretary described the work of the new division of radiation and organisms, and spoke of the interest shown in the Institution by the Research Corporation of New York, of which he is a director. He stated that for the past three years the corporation had in each year made a grant to the Institution of $15,000 to promote the work of the division of radiation and organisms. He also called attention to the large sums that had been given by Mr. John A. Roebling to the Institution for its work in solar radiation and for other purposes, and stated that Mr. Roebling had very recently added a fund for the purchase of books of reference on the subjects relating to radiation investigations.

## SPECIAL MEETING OF MAY 29, 1930

Present: Chief Justice Charles Evans Hughes, Senator Joseph T. Robinson, Senator Claude A. Swanson, Representative Albert Johnson, Representative R. Walton Moore, Representative Robert Luce, Mr. Robert S. Brookings, Mr. Frederic A. Delano, Dr. John C. Merriam, and the secretary, Dr. C. G. Abbot. Mr. Delano was invited to act as temporary chairman.

The secretary said that the appointment of Mr. Charles Evans Hughes as Chief Justice of the United States takes him from the list of "citizen" regents who are appointed for six years, and constitutes him under the law an ex officio regent with a life tenure. He said further that a vacancy existed in the office of chancellor, and the following resolution was adopted:

*Resolved,* That the Board of Regents of the Smithsonian Institution hereby elects the Hon. Charles Evans Hughes, Chief Justice of the United States, as chancellor of the Institution.

The chancellor then took the chair, expressing his appreciation of the honor done him.

The secretary said that in view of the resignation of Chief Justice Taft, the Board of Regents, at their meeting of February 13, 1930, had adopted resolutions which had been transmitted to the Chief Justice, and which had been acknowledged.

The secretary spoke of the development of his researches on the radiation of the sun, and then called attention to the provisions of the new civil service retirement act, which makes possible the continuance in the service of the Institution of certain members of the staff who would otherwise have to retire on August 20, 1930.

The secretary stated that beginning in 1911, letters had been received from a Mr. James Arthur, of New York City, asking certain information, including problems in mathematics, which had been carefully answered. Recently, word had been received that Mr. Arthur had bequeathed to the Institution the sum of $75,000, the income of which was to be used for (*a*) the investigation and study of the sun; (*b*) to provide annually a lecture to be known as the James Arthur Annual Lecture on the Sun. Mr. Lloyd N. Scott, a director and the counsel of the Research Corporation of New York, had been designated as the legal representative of the Institution in connection with matters pertaining to this bequest.

The secretary said that the Senate had passed a bill authorizing the preparation of plans for the construction of wings on either side of the museum building at a cost of $6,500,000. The bill as passed was an authorization only, but had not yet been brought before the House. On motion, the secretary was requested to prepare a resolution embodying the sense of the board as to the urgency of the matter, and requesting that the chancellor present the same to the President.

The secretary added that efforts had been made to fix a date for the presentation of the Langley gold medals to Admiral Byrd and (posthumously) to Charles M. Manly, but that this had not yet been accomplished.

# GENERAL APPENDIX

TO THE

# SMITHSONIAN REPORT FOR 1930

# ADVERTISEMENT

The object of the GENERAL APPENDIX to the Annual Report of the the Smithsonian Institution is to furnish brief accounts of scientific discovery in particular directions; reports of investigations made by collaborators of the Institution; and memoirs of a general character or on special topics that are of interest or value to the numerous correspondents of the Institution.

It has been a prominent object of the Board of Regents of the Smithsonian Institution from a very early date to enrich the annual report required of them by law with memoirs illustrating the more remarkable and important developments in physical and biological discovery, as well as showing the general character of the operations of the Institution; and, during the greater part of its history, this purpose has been carried out largely by the publication of such papers as would possess an interest to all attracted by scientific progress.

In 1880, induced in part by the discontinuance of an annual summary of progress which for 30 years previously had been issued by well-known private publishing firms, the secretary had a series of abstracts prepared by competent collaborators, showing concisely the prominent features of recent scientific progress in astronomy, geology, meteorology, physics, chemistry, mineralogy, botany, zoology, and anthropology. This latter plan was continued, though, not altogether satisfactorily, down to and including the year 1888.

In the report for 1889 a return was made to the earlier method of presenting a miscellaneous selection of papers (some of them original) embracing a considerable range of scientific investigation and discussion. This method has been continued in the present report for 1930.

# BEYOND THE RED IN THE SPECTRUM[1]

By H. D. Babcock

[With 2 plates]

One result of the widespread use of radio is a general familiarity with two terms which have long been household words among astronomers and physicists—wave length and frequency. Although some vagueness often adheres to the meaning of these words, they are exceedingly useful to everyone who uses a radio receiving set. What matter if the machinery inside the box is permanently mysterious, provided a scale on the outside allows one to select the station he wishes. We all soon learn the proper scale readings to find our favorite stations, and we are accustomed to hear the announcer make his routine statement: "This station operates at a frequency of so many kilocycles by authority of the Federal Radio Commission."

In such an ordinary experience as the use of the radio, a point of contact is found with the subject of our discussion—Beyond the Red in the Spectrum. We shall view this topic in its perspective relation to the whole known range of wave lengths, trace a bit of the history of its discovery and development, examine some of the modern methods of studying it. If some idea is conveyed of the reasons why these studies are worth while, our purpose will have been in part accomplished. If, in addition, something of the fascination which attends this kind of work is revealed, so that further acquaintance with it appears desirable to you, the results will be still more satisfactory.

Now as to radio waves, most of us are chiefly interested in the ordinary broadcasting which may be received with our familiar receiving sets. Such wave lengths, as everyone knows, range from 500 meters down to 200 meters—a difference corresponding to a little over one octave in terms of the musical analogy. Only, instead of having just 13 notes in the octave, our radio octave is now divided into some 55 specified wave lengths. Outside the reach of the

[1] A lecture delivered before the Carnegie Institution, at Washington, D. C., Dec. 10, 1929; and at Pasadena, Calif., Feb. 20, 1930. Reprinted by permission from publications of the Astronomical Society of the Pacific, vol. 42, No. 246, April, 1930.

ordinary receiver, however, other radio waves exist, and all that is necessary to intercept them is a receiving set suitably designed. Thus we have radio wave lengths ranging from a few meters to many kilometers, all having the same physical nature and traveling through space with the same velocity.

In order to make more definite the idea of the relative magnitude of different wave lengths reference may be made to Figure 1. Here is represented the region of the ordinary radio waves, and, following along the scale, we find a succession of other types of waves, all of which, however, are physically alike, just as all sound waves are alike, though differing in pitch. Here you see the place occupied by the visible waves, here the ultra-violet and the famous cosmic radiation, of which so much is lately heard. This diagram, doubtless familiar to many of you, is shown especially to point out the location of the particular field selected for discussion—beyond the red, but not indefinitely beyond. It also illustrates the fact that in a broad sense we are all exceedingly color blind.

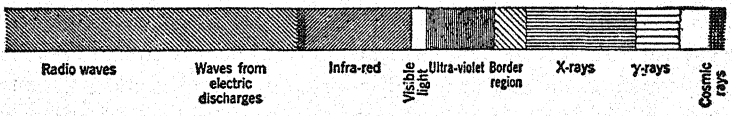



FIGURE 1.—The octaves of light from The World of Atoms, by Arthur Haas, English translation by H. S. Uhler. By permission of the D. Van Nostrand Co.

Having seen the setting of our subject, let us consider a little of its history. All astronomers honor the name of Sir William Herschel, who with his son, Sir John, contributed so much to our knowledge of the universe. His enthusiasm, skill, and insight brought rich returns. He explored the depths of space with an unprejudiced mind, the gift of his Creator, and an excellent telescope, which he made for himself. He sought a way to use his powerful instrument for visual examination of the sun; how to avoid the disastrous effects of too much heat and light in the eyepiece without sacrificing the power of his instrument. This led Sir William to make the first investigation of what lies beyond the red in the spectrum of sunlight. With a glass prism, three ordinary thermometers, a watch, some boards and paper screens, he carried out a remarkable series of observations, an account of which he published in the year 1800 in the Philosophical Transactions of the Royal Society of London under the title "Investigation of the Powers of the Prismatic Colours to Heat and Illuminate Objects."

In this paper Herschel gives a most interesting description of his experimental work. He relates in detail how one thermometer was exposed to the infra-red part of the solar spectrum, while the others

were near-by but shaded from the spectrum. By reading all three at regular intervals of time he found that the exposed thermometer rose at a faster rate than the others. Pushing the thermometers along the spectrum, he explored a considerable extent of the new region which he had discovered, and was able to learn something of the distribution of energy in it.

Later, by an improvement of this method of study, Sir John Herschel, son of Sir William, continued the examination of the invisible spectrum. He concluded that one-half of the sun's heat is found in the infra-red part of the spectrum—a result surprisingly close to the modern figure of 45 per cent. The important result of the Herschels' work was the demonstration that visible radiation is only a part of the spectrum, and that nonluminous hot bodies have spectra just as those which we can see by their own light.

Leaving the work of the Herschels, on which it would be easy to spend all the time available here, we shall next consider the contributions of Professor Tyndall, the famous English physicist who lived in the middle of the last century. With apparatus far more delicate than that of his predecessors (though it would appear crude to us to-day) he devoted years to a thorough study of the phenomena of heat, covering both the visible and the infra-red parts of the spectrum. To give an adequate idea of the scope and the importance of Tyndall's brilliant experimental work would take far too long. It furnished a sure foundation of established facts on which later the great theoretical treatment of radiation was to be laid, and it still constitutes a rich fund of information. Tyndall studied, among many other things, the absorbing power of gases for radiation. I think he was the first to recognize the remarkable difference in the absorbing power exhibited by a mixture of certain molecules and by a chemical combination of the same molecules.

For example, if a certain number of molecules of oxygen are mixed with twice as many of hydrogen, the power of the mixture to absorb infra-red radiation is very small. But if these same molecules are combined chemically to form water vapor, the absorptive power is much greater. This fact finds a unique explanation in the modern theory of molecular structure.

Another problem which Tyndall undertook to investigate was to find the proportion in which the total energy radiated by a hot body is divided between visible and obscure portions of its spectrum. This proportion is known as the luminous efficiency. For example, we have already seen that in the case of the sun the luminous efficiency is roughly 50 per cent. Tyndall thus greatly extended the study of the distribution of energy in the spectrum of a hot body, which had been begun by Sir William Herschel. One of Tyndall's

demonstrations, somewhat modified, is illustrated schematically in Figure 2. The infra-red radiation emitted by a hot wire is isolated by a solution of iodine in carbon bisulphide, which absorbs the visible but permits the infra-red to pass through. When concentrated at the focus of a mirror the invisible radiation ignites a match in a few seconds.

By such means and others, Tyndall was able to find in what proportion the total energy radiated by a hot body is divided between visible and obscure portions. The relation of this proportion to the temperature of the body, accurately formulated by the theoretical physicists Wien and Planck, is a most valuable tool for both the astronomer and the physicist. Two applications of this idea may be noted here. The first is the method of determining stellar or planetary temperatures by finding the distribution of energy in their spectra. For example, the image of a star is formed at the focus of a telescope on a tiny receiver which has been blackened in order that it may absorb all the radiation which falls on it. Delicate electrical

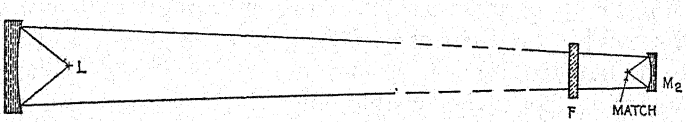



FIGURE 2.—Diagram of one of Tyndall's demonstrations. A match placed as indicated is quickly ignited by invisible infra-red radiation from an electric lamp, although match and lamp are several yards apart. *L*, an electric street lamp; $M_1$, $M_2$, concave mirrors; *F*, liquid filter which absorbs visible but transmits infra-red radiation

devices indicate the slightest change occurring in the temperature of the receiver. Filters of various kinds, corresponding to the iodine solution indicated in Figure 2, permit the separate measurement of visible and invisible radiation and thus the ratio of these quantities is obtained, leading to a knowledge of the temperature.

A second illustration is connected with recent events of world-wide interest. When Mr. Edison's golden anniversary was celebrated he once more constructed an electric lamp like his first of 50 years ago. The contrast between such early lamps and those in common use now is indeed striking. The improvements have resulted from a knowledge of the distribution of energy between the visible and the obscure parts of the spectrum. This has led to the operation of modern lamps at far higher temperatures than were formerly used, with resultant increase of luminous efficiency. These two lamps which I now turn on are consuming nearly the same power. One is a type in wide use 20 years ago, the other a modern form. It is evident that the brightness of the modern lamp is much greater than that of the old one.

We pass on to the more detailed study of the infra-red part of the spectrum, where we shall deal no longer with the continuous spectra of incandescent bodies, but with spectra of different type which are produced by atoms and molecules acting as individuals. Now atoms are in one respect like opera singers—in their most striking and individual rôles each requires plenty of elbowroom. Though the analogy is imperfect, the continuous spectrum of a glowing solid may be compared to the chorus, while the line spectrum of a luminous gas is more like the song of the prima donna, who passes from one degree of excitation to another, emitting a rapid succession of musical notes like the brilliantly colored lines which individual atoms produce, when far enough apart from each other, and suitably stimulated.

When closely bound together as in a solid substance, the atoms tell us the temperature of the solid, but only little of themselves. When the solid is turned to gas by heating it sufficiently, the atoms get far apart and then have an opportunity to do many things otherwise impossible for them. Thus each kind of atom, whether it be hydrogen or iron, sends out a characteristic spectrum consisting of numerous kinds, or colors, of light, each very sharply defined. Some of these "colors" are invisible but readily perceptible by instruments suitably designed. Each separate color is referred to as a spectral line. The supply of names for these colors soon proved inadequate and numbers are now used instead.

Let us consider the case of hydrogen, with only some 50 or 60 lines in its spectrum, and think of each atom of the gas, mingled with countless others all alike, as a magician having a repertoire of tricks. At a given moment each atom can perform just one of its various tricks, and the performance, practically instantaneous, is to produce light of a certain color. A neighboring atom may be performing a different trick, but it is one of the same repertoire. The combined activities of all the atoms display the whole repertoire. At a later time each atom may be doing a different trick from the one it formerly showed, but the combined effect is the same as before. Each trick corresponds to a line in the spectrum of hydrogen, and the intensity of the line is a measure of the preference which the atoms have for certain of their tricks. Every other kind of atom such as oxygen, or zinc, has a characteristic repertoire. Each kind may be recognized by its spectrum even under diverse conditions.

Near the beginning of this century a great physicist, Professor Planck, to whom we have already referred, formulated a theory of radiation which is known as the quantum theory. This important work grew out of Planck's study of the total radiation of a solid black body. In 1913 Professor Bohr developed an application and extension of Planck's theory to the problem of line spectra emitted by iso-

lated atoms, and he succeeded in accounting for the known spectrum of hydrogen with astonishing accuracy and completeness. By calculations based on this theory he showed that the known lines of the hydrogen spectrum should be precisely where we find them. Furthermore, he predicted the exact position of other lines which the hydrogen atom should emit, and these were afterward observed precisely where he said they should be. This brilliant success was followed by a rapid expansion of our understanding of all line spectra and of the atoms which give rise to them.

A basic idea in Bohr's theory of spectra is this: Whenever an atom produces one of its characteristic pure colors the energy thus sent out in the form of radiation is exactly equal to the energy lost by the atom as a result of the rearrangement of its parts. The atom is thought of as having a heavy inner part or nucleus, with one or more much lighter electrons bound to it by electrical forces. The analogy with the structure of the solar system is obvious and to some extent helpful, but it must not be carried too far. For example, the planes of the planetary orbits lie within a few degrees of each other in the solar system, while in the atoms this is not necessarily true. When one of the outer electrons in an atom assumes a new position nearer to the nucleus the atom accomplishes a definite amount of work, and the energy radiated away is the exact equivalent of this work. If a weight is allowed to fall from table to floor a certain amount of work is done. Its equivalent is found in the heat developed, the sound waves set up, and sometimes also in other ways.

Each line in a spectrum thus signifies the existence of two states of the atom in which the internal energy of the atom is different. A line whose color is red arises from a transition between two states not very different; a line in the ultra-violet, from a transition between states having a much greater difference of energy. If your baby falls off a footstool he may express his annoyance by a moderately pitched exclamation; if he falls downstairs he will emit vocal sound waves at least an octave higher. The color of a spectral line, accurately expressed on a frequency scale, tells exactly the energy lost by the atom when it performed one of its tricks.

The physicist measures the positions; i. e., the "colors," to speak loosely, of the spectral lines with an accuracy almost unbelievable; he notes the relative intensities of the lines, their individual peculiarities such as sharpness or diffuseness, their varying behavior under change of conditions surrounding the source of light, such as presence or absence of a magnetic field; and gradually he learns, for each kind of atom, the system of energy-states which it possesses. These energy-states, or spectral terms as they are called, are less numerous than the lines in the spectrum, and are far more significant of the

nature of the atom. Thus in the spectrum of neon some 900 lines represent transitions between only 26 spectral terms.

These terms or energy-states themselves correspond to different arrangements of the electrons which make up the outer part of the atom. Thus a knowledge of the terms, which is derived from the observed spectral lines, brings us some definite idea of the mechanics of the atom.

The periodic table was long ago recognized by chemists as expressing some fundamental relations between the elements. By comparison of the spectra of elements adjacent in this table, the physicist is now able to trace, in part at least, the gradual increase in mechanical complexity of the atoms with their increase of weight. The most fundamental physical and chemical relationships are thus clarified, and man's mastery of his environment is definitely increased.

This digression from the infra-red part of the spectrum has been necessary in order to show in some fashion what the spectroscopist is trying to do, regardless of the spectral region in which he works. As we have seen, the object is to obtain, by a study of its spectral lines, as complete a picture as possible of the system of terms associated with each kind of atom and from these to derive the structure of the atom. To do this a large range of wave-lengths must be examined; it is not sufficient to measure just the blue part of the iron spectrum and attempt to find all the terms from the lines shown there, for terms may exist whose combinations give no blue lines at all. Even the entire visible spectrum is inadequate, and it becomes necessary to study the ultra-violet and the infra-red in order to fill in all the details.

These are some of the reasons which justify the activities of the spectroscopist and warrant his efforts to extend the photographic study of atomic spectra into the infra-red. Two other promising fields of study also invite the more detailed exploration of the region of longer wave lengths, namely the spectra which are characteristic of molecules as distinguished from atoms, and the solar spectrum. The complexity of molecules as compared to atoms is obvious, since a molecule is a cluster of two or more atoms which have approached each other close enough to form a partnership. Indeed the structural complexity is reflected in the spectra which molecules give. Such spectra present many individual lines corresponding to a single electronic transition in the molecule, because the atoms which make up the molecule are free to rotate and to vibrate with respect to the center of mass, and each of these possibilities is utilized every time the electrons are rearranged. Thus the spectra of molecules have furnished information of the utmost importance to the chemist as well as to the physicist. For example, accurate determinations of

the distance between the two nuclei in a diatomic molecule, of the moment of inertia of the molecule, of its heat of dissociation, as well as the discovery of isotopic forms of the atoms and the calculation of their masses are all possible in favorable cases where the band spectra are suitable for precise measurement. To interpret the value of each of these results, which have actually been obtained for oxygen molecules, would lead us far into fields remote from our topic. To apply improved methods of observing the infra-red region of molecular spectra is bound to aid in developing this rapidly expanding department of spectroscopy.

We are thus brought to the third field of large-scale spectroscopy, namely, the study of the solar spectrum. Here we pause to pay respect to the genius of Professor Rowland of Johns Hopkins University, who carried out a remarkable investigation of the visible and ultra-violet parts of the solar spectrum, which has been a storehouse of information for 30 years. Some 20,000 spectral lines were measured and described with an accuracy only recently surpassed. There is no doubt that Rowland would have extended his researches into the infra-red part of the spectrum if he had possessed photographic plates which would respond to such radiation.

For years it has been comparatively easy to photograph much of the ultra-violet and all of the visible region of the spectrum, and the method of photographic spectroscopy has proved superior to all other ways of determining the exact positions and characters of spectral lines. As we go beyond the visible red, however, the photographic process becomes increasingly difficult and finally has to be replaced by the thermometric method.

The thermometric method, as its name implies, depends on measurement of the heating power of radiation. For this purpose three types of instrument are in use, two of which utilize electrical effects and the other, a mechanical effect of the radiation. Instruments of the first two kinds are called bolometers and thermocouples, while the third is known as a radiometer—and has been seen by every one in the windows of opticians and jewelers.

It would be interesting to describe the working of these marvelous devices and to show the results which they produce. It must suffice to consider briefly the application of the bolometer to the study of the solar spectrum. This instrument was invented by Professor Langley at the Allegheny Observatory in 1881. Subsequently as Secretary of the Smithsonian Institution he used it with the assistance of Dr. C. G. Abbot, the present secretary, to explore in detail the infra-red solar spectrum. In the 30 years following the publication of this great work, Doctor Abbot has continued to improve the instrument and to apply it in a series of brilliant researches. During the past year, with the assistance of Mr. Freeman, Doctor Abbot has published

the latest measurements of this part of the solar spectrum from observations made by them at Mount Wilson in 1928.

The bolometer depends on the change of electrical resistance shown by a metal whose temperature is varied. A delicate electrical recording device draws a continuous curve whose ordinates indicate the temperature of a hairlike filament of blackened platinum, across which the solar spectrum is made to pass. Figure 3 shows such a curve obtained by Doctor Abbot. The electrical connections are so made that when the curve dips down it means that the filament became cooler. Thus these notches mean dark lines or bands interrupting the continuity of the spectrum, exactly similar to the well-known Fraunhofer lines in the visible spectrum of the sun. The wave lengths here recorded are from λ7,600 at one end to about λ20,000 at the other. The thermometric method is capable, as you see, of working over an enormous range of wave lengths, greater in fact than the photographic method. It has another advantage in that

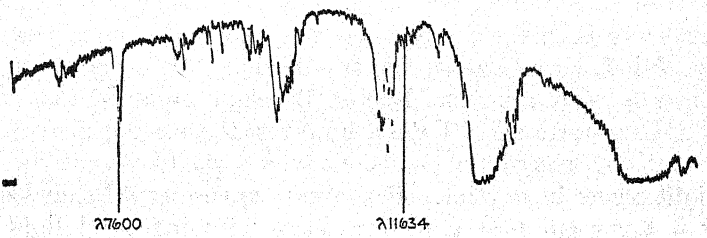



FIGURE 3.—Bolometric record of solar energy in the infra-red, made by Dr. C. G. Abbot. Beginning at the left with very deep red visible radiation, the curve extends to the right far beyond the limits of visibility and also beyond the present limit of photography

it gives, more directly than the photographic method, the intensity of the radiation at each point in the spectrum. On the other hand photography permits the observation of finer details than the thermometric method, and leads to higher accuracy. A real advantage is found, therefore, in observing, in so far as possible, the same part of the solar spectrum by both the thermometric and the photographic methods. The greater accuracy of photography serves to calibrate the wave-length scale of the bolometer, while the bolometric record shows that the spectral lines recorded by the photographs are real and not spurious effects introduced by the apparatus.

Nearly 50 years ago Sir William Abney photographed the invisible solar spectrum as far as the point indicated on the curve—λ9,867. Attempts to extend his work have failed, although a few years ago Dr. F. S. Brackett, then at the Mount Wilson Observatory, succeeded in reaching a point just short of Abney's limit. We shall now consider some recent advances in the photographic method which have made it possible to use it as far as λ11,634.

Abney obtained his results with a special form of silver bromide which had the power of absorbing red and infra-red radiation; he used no dyes. He prepared his own photographic plates shortly before use by an elaborate process which he described in detail. But his process is troublesome and uncertain. It has never been seriously applied to modern spectroscopy, although the resources of the present chemical laboratory would perhaps warrant a revival of it. Since Abney's day, photographic chemistry has been more concerned with ordinary silver bromide, which of itself absorbs only blue, violet, and ultra-violet light. To make this bromide useful for longer wave lengths, dyes are added to the emulsion which, by their absorption of the yellow, red, or infra-red, are designed to confer sensitivity to those kinds of radiation. This is the method used in preparing panchromatic emulsions with which many of you are no doubt familiar. Commercial needs have so stimulated the perfection of such emulsions that those now obtainable are of excellent quality. For the infra-red, however, the commercial requirements have not been so great and progress has been much slower. For many years only one useful dye was known for this region. It is called dicyanine and it was with this that Doctor Brackett obtained his excellent results some years ago. Lately, however, the motion-picture industry developed a need for emulsions which would permit the taking of night scenes in daytime, since great expense could thus be saved. Now it turns out that a picture made with infra-red light under ordinary daylight conditions looks very much as though it has been made at night. In such a picture the sky, for example, is dark instead of light. (See pl. 1.) Perhaps then, the spectroscopist owes something to the movies for the fact that not long ago two new dyes were produced by the Eastman Kodak Laboratory under Doctor Mees's direction. One of these is particularly important for our purpose, and it is the outcome of using it that we shall now hear. This new dye is called neocyanine. It is produced in the form of beautiful red crystals which are soluble in alcohol. An ordinary photographic plate soaked in this solution acquires infra-red sensitivity far beyond that obtainable with other dyes. It has thus become feasible to use instrumental power which is comparable with that employed in the visible part of the spectrum and sufficient to bring out a wealth of detail beyond the power of the thermometric methods.

For this purpose the solar spectrum is formed by an optical instrument called a concave grating, especially constructed to give exceptional brightness to the spectrum. A small image of the sun is formed on the slit of the spectrograph which is covered by a filter. This stops the visible light and transmits only the invisible

infra-red rays. The plate is exposed to these about 7 hours and then developed in total darkness. Perhaps you can imagine the impatience with which the observer waits while the plate fixes sufficiently to permit a glimpse in weak light to see whether he got anything on it or not.

It turns out that just twice as much of the solar spectrum can now be studied by photography as in the day of Professor Rowland, with the result that hundreds of spectral lines produced by atoms in the sun's atmosphere are being accurately measured for the first time. From what has been said about the significance of a line in the spectrum it will be evident that such new data are valuable to the physicist as well as to the astronomer. The physicist sees in the sun's atmosphere a laboratory in which about two-thirds of the elements known on earth are trying to tell him the story of their structure. The astronomer sees new opportunities to examine the constitution of our nearest star and so to understand what all stars are like.

Carbon is an element abundant in the earth. We should expect it to be abundant in the sun also, since the best tests we can make indicate that the earth is a fair chemical sample of the material universe. Hitherto the only evidence for the presence of atomic carbon in the sun has been found in nine faint lines in the visible part of the spectrum. Although doubtless conclusive, this evidence is not very impressive when compared to that for other equally abundant elements. The fact is that throughout the visible and near ultra-violet region, carbon atoms have no strong lines and only a few weak ones. When studied in the electric arc, however, the carbon atom is known to produce a group of very strong lines in the infra-red. The new solar spectrograms show these same lines; but since the accuracy here is greater than in the case of the electric arc, the solar data more completely correspond with the predictions of the atomic theory than do those of the laboratory.

Perhaps we have talked of too many things in the course of the hour, and some of them were not interesting to you. But, although tiresome details may soon be forgotten, some general impressions may remain. One which I should like to leave with you in closing is that of the continuity of scientific progress. Some writers who interpret scientific news in popular magazines and in newspaper articles emphasize what they call the revolutionary discoveries and theories of recent years. This no doubt attracts the eye of the general reader, and at any rate reminds him that science is alive. But a much truer perspective is had by omitting just one letter in such headlines and thus bringing out the fact that most important scientific advances are evolutionary in character, not revolutionary.

Illustrations abound on every hand, but the subject of our discussion here is apropos. The Herschels, father and son, Tyndall, Bunsen, Kirchoff, Wien, Planck, Bohr, and, preceding these, Newton, form a succession no one of whom overthrew the work of his predecessors. Instead, before each one saw a little deeper into the pure spring of truth, he first established himself on the foundation already laid for his use. Einstein does not overthrow Newton; he adds to Newton's truth.

Listen to Alfred Noyes, writing of Newton:

> "If I saw farther, 'twas because I stood
> On Giant shoulders," wrote the king of thought,
> Too proud of his great line to slight the toils
> Of his forebears. He turned to their dim past,
> Their fading victories and their fond defeats,
> And knelt as at an altar, drawing all
> Their strengths into his own; and so went forth
> With all their glory shining in his face,
> To win new victories for the age to come.
>
> So, where Copernicus had destroyed the dream
> We called our world; where Galileo watched
> Those ancient firmaments melt, a thin blue smoke
> Into a vaster night; where Kepler heard
> Only stray fragments, isolated chords
> Of that tremendous music which should bind
> All things anew in one, Newton arose
> And carried on their fire.
>
> * * * he caught
> The sunbeam striking through that bullet-hole
> In his closed shutter—a round white spot of light
> Upon a small dark screen. He interposed
> A prism of glass. He saw the sunbeam break
> And spread upon the screen its rainbow band
> Of disentangled colours, all in scale
> Like notes in music; first the violet ray,
> Then indigo, trembling softly into blue,
> Then green and yellow, quivering side by side;
> Then orange, mellowing richly into red.

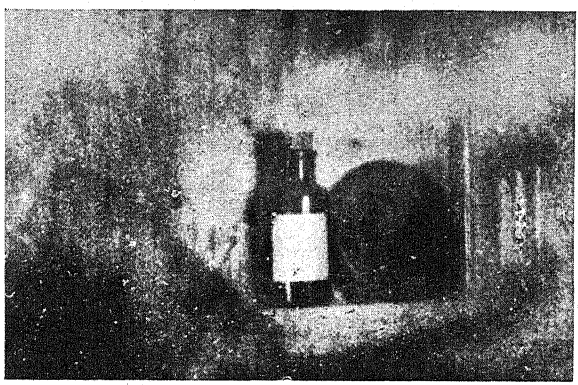
Here Newton stopped; and here Herschel began the long-continued, still progressing, sightless but not unseeing search, Beyond the Red in the Spectrum.



1. FROM A PHOTOGRAPH MADE WITH ORDINARY LIGHT ON A PANCHROMATIC PLATE WITH LIGHT YELLOW FILTER



2. FROM A PHOTOGRAPH MADE WITHIN 30 SECONDS OF FIGURE 1, BUT WITH A SPECIAL PLATE AND FILTER SO THAT ONLY INFRA-RED RADIATION IS EMPLOYED



PICTURE MADE IN TOTAL DARKNESS, USING ONLY INVISIBLE RADIATION FROM ELECTRIC HEATERS CARRYING INSUFFICIENT CURRENT TO MAKE THEM GLOW EVEN IN A DARK ROOM. PLATE SENSITIZED WITH NEOCYANINE

# GROWTH IN OUR KNOWLEDGE OF THE SUN[1]

By CHARLES E. ST. JOHN

[With 7 plates]

The differences between the two representations of the sun (pl. 1) show graphically the wide contrast between the appearance of the sun as observed and imagined in 1635, and as photographed nearly 300 years later as a composite of spectroheliograms of disk and chromosphere.

The gulf between the past and the present knowledge of the sun has been bridged in comparatively recent years, almost within the lifetime of men now living.

Though absorption lines in the solar spectrum were first observed by Wollaston in 1802 and catalogued to the number of 576 by Fraunhofer in 1814, the real beginning of astrophysics dates from Kirchoff's great discovery, in 1859, of the true interpretation of the Fraunhofer lines. The application of spectroscopic analysis to astronomical problems opened broad vistas to active and progressive spirits. Huggins says, "The news of Kirchoff's discovery was to me like coming upon a spring of water in a dry and thirsty land." The first triumphs of the spectroscope were won by its application to the sun. It is interesting to note, however, that in the hands of Huggins and Draper the novel method of research was extended to stars, nebulae, and comets with great success before further uses were found for it in solar work.

Lockyer and Janssen in 1868 made a great advance through their independent observations that the blood-red chromosphere and prominences, hitherto seen only during a total eclipse of the sun, are gaseous and owe their redness to the emission of the red line of hydrogen; and by the discovery of helium in the sun a quarter of a century before it was traced to an earthly source. A romantic touch was thus given to the study of the sun.

[1] Reprinted by permission, with author's alterations and additions, from Publications of the Astronomical Society of the Pacific, vol. 41, No. 241, June, 1929.

## COMPOSITION OF SUN'S ATMOSPHERE

The identification of solar lines with those of the known terrestrial elements, begun by Kirchoff, was taken up by Rowland, whose extensive findings were incorporated in his Preliminary Table of Solar Spectrum Wave Lengths, published in 1896. For a third of a century this has been the world's standard, and the vade-mecum of astronomers, chemists, and physicists. In the Revision[2] recently completed at Mount Wilson Observatory, the original identifications have been checked and corrected by the use of all available data conjointly with modern astrophysical theory and the results of spectrum analysis. Nearly all, viz. 35, of the elements recognized or suggested by Rowland as present in the sun, have survived the critical examination and retain their place as components of the sun's atmosphere. To these, 26 have been added, so that 61 of the 90 known elements are represented with varying degrees of probability. Of particular interest and importance among the results of the Revision are the identification of the nonmetallic elements—carbon, nitrogen, oxygen, and sulphur in the atomic state; the large proportion of the metals occurring in both the neutral and ionized states; the complete ionization of the rare-earth metals; and the importance of the rôle of excitation potential.

The identification rests upon reasonable correspondence between the positions of solar and laboratory lines, so-called coincidence. For iron this is shown in Plate 2, Figure 1, at A, where it is seen that the bright arc lines of iron are well represented in the sun's spectrum. This is a reproduction of a spectrogram made by simultaneous exposures to the center of the sun and to the luminous vapor between the two poles of an iron arc.

Identifications are furnished also by flash spectra. When the sun's disk is covered by the moon at a total eclipse only the glowing gases of the sun's atmosphere are exposed to view beyond the moon's edge. These then give bright lines which, except in the case of helium, are the reversals of the dark Fraunhofer lines. This may be seen in Plate 3, for the strong iron triplet λλ4,045, 4,063, 4,071. Normally helium gives bright lines which appear only in flash and prominence spectra. The helium line λ4,026 is conspicuous in the reproduction.

The symbols of the 90 known chemical elements are given in Table I.

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[2] Revision of Rowland's Preliminary Table of Solar Spectrum Wave Lengths, with Extension to the Present Limits of the Infra-Red, Carnegie Institution of Washington, Publ. No. 396; Papers of Mount Wilson Observatory, Vol. III, 1928.

TABLE I.—*Elements identified in the sun and their position in the periodic table*

[Unidentified elements in parentheses]

| I | II | III | IV | V | VI | VII | VIII | | |
|---|---|---|---|---|---|---|---|---|---|
| *H* | | | | | | | *He* | | |
| *Li* | *Be* | *B* | *C* | *N* | *O* | *(F)* | *(Ne)* | | |
| *Na* | *Mg* | *Al* | *Si* | *(P)* | *S* | *(Cl)* | *(A)* | | |
| *K* | *Ca* | *Sc* | *Ti* | *V* | *Cr* | *Mn* | *Fe* | *Co* | *Ni* |
| *Cu* | *Zn* | *Ga* | *Ge* | *(As)* | *(Se)* | *(Br)* | *(Kr)* | | |
| *Rb* | *Sr* | *Y* | *Zr* | *Cb* | *Mo* | *(Ma)* | *Ru* | *Rh* | *Pd* |
| *Ag* | *Cd* | *In* | *Sn?* | *Sb* | *(Te)* | *(I)* | *(Xe)* | | |
| *(Cs)* | *Ba* | *La** | *Hf* | *(Ta)* | *W* | *(Re)* | *Os?* | *Ir?* | *Pt* |
| *(Au)* | *(Hg)* | *Tl?* | *Pb* | *(Bi)* | *(Po)* | 85 | *(Rn)* | | |
| 87 | *(Ra)* | *(Ac)* | *(Th)* | *(Pa)* | *(U)* | | | | |

* RARE EARTHS

| | | | | | | |
|---|---|---|---|---|---|---|
| *Ce* | *Pr* | *Nd* | *(Il)* | *Sa* | *Eu* | *Gd* |
| *Tb?* | *Dy* | *(Ho)* | *Er?* | *(Tu)* | *Yb?* | *Lu* |
| Probably all in the ionized state | | | | | | |

Mount Wilson Observatory

Those in parentheses are as yet unidentified in the sun's atmosphere. This does not necessarily mean that these unidentified elements are absent. For some elements the lines of lowest excitation potential, the resonance lines, are far in the ultra-violet beyond the accessible regions in both stellar and solar spectra. A layer of ozone situated some 50 miles above the earth's surface absorbs the radiations to the violet of λ2,975 A. The strong resonance lines of the neon and fluorine groups are in this region. The question marks mean that the evidence is not strong and that exact laboratory wave lengths are wanting as in the case of osmium and iridium. Eventually such elements will be found to be definitely present or absent.

Ninety of the ninety-two possible elements have been found on the earth. The heavy elements in the bottom line are all radioactive.

The end results of the radioactive changes are helium and lead which are being formed continually from their ultimate sources, thorium and uranium, through the more highly radioactive elements in the series of transformations. That these do not appear in the sun may be due in part to their radioactive degeneration, and the ending of the series of elements with uranium, at No. 92, the heaviest element, may be due to the disappearance of possibly heavier elements through their radioactivity, so that we have left the more stable ones which have proved the fittest to survive.

## ASTROPHYSICS

The methods introduced by Huggins and Lockyer of interpreting astronomical spectra through observations in the physical laboratory led to the development of astrophysics, as a branch of physical science. Confirmation of the soundness and fruitfulness of these methods could be drawn from many sides. An outstanding illustration is the work of Hale and his co-workers, who have brought us to the present view of the constitution of sun spots as great vortices whose centers are magnetic fields which may in the larger spots reach intensities of 4,000 gausses over areas of many millions of square miles.

## MAGNETIC FIELDS IN SUN SPOTS

Many lines in the spectra of sun spots taken with sufficiently high dispersion are doubled or tripled, depending upon the strength of the magnetic field and the angle between the lines of force and the path of the light. The components of the doublets were found by Hale to be circularly polarized in opposite directions. In the laboratory similar doubling with circular polarization of the components is observed when the light source is placed between the poles of a powerful magnet and the light emitted by a spectrum line is viewed in a direction parallel to the lines of the magnetic field. Viewed in any other direction, the line is a triplet, the middle component plane, and the two side components elliptically polarized; except when normal to the field, when the two side components are plane polarized at right angles to the plane of the central component. The illustration (pl. 4, fig. 1) shows the Fe line, $\lambda$6,173, photographed as an absorption line in a sun spot and as an emission line in the laboratory (the insert). The horizontal bands are due to quarter-wave mica strips with their optical axes at right angles to each other in the alternate bands. These change the circular or elliptical vibration of the side components into plane vibrations at right angles to each other in the alternate bands. A Nicol prism in the optical train cuts out the blue and transmits the red (side) com-

ponent in one strip and cuts out the red and transmits the blue component in the following strip and so on alternately, producing the staggered effect. In the case shown, the light from the spot was not viewed exactly parallel to the lines of the magnetic field, hence there is a weak middle component, while in the laboratory observation there is no central component, the line of sight in this case being parallel to the lines of the magnetic field. As the separation of the components observed in the laboratory for a given line is proportional to the strength of the magnetic field, the intensity of the field in a spot is deducible from the separation of the components of the same line in its spectrum. The magnetic fields in sun spots are attributed to the rapid rotation of electrically charged particles in deep-seated vortices in which the gases are in cyclonic rotation. The low temperature, some 2,000° C. below that of the general surface, was first shown by interpreting the differences between the spectra of the photosphere and the spot umbra in terms of laboratory observations, and was later deduced from the theory of ionization.

The polarity of the leading spot in a bipolar group in the Northern Hemisphere is opposite to that of the leading spot in the Southern Hemisphere, during a given 11-year cycle. The polarities reverse at the beginning of each new spot-cycle, the complete magnetic period being double that between spot minima. The general magnetic field of the sun is relatively weak but was detected by methods similar to those applied to spots, although still more refined measures were necessary. It has an intensity at low levels in the reversing layer of 50 gausses. The magnetic axis is 4° from the sun's axis of rotation and revolves around it in 31.5 days.

## DOPPLER EFFECTS

Lockyer's use of the Doppler principle to explain the distortions of bright chromospheric lines was the first introduction of it into solar investigation, where it has played a preeminent rôle.

It has been applied to determining the rotation of the sun by photographing in juxtaposition the spectra of the east and west edges of the sun. (Pl. 2, fig. 2.) The center strip is from the east limb and the two outer from the west limb. A careful examination will show that the Fraunhofer lines from the east and west limbs are mutually displaced. The displacement at the east limb to shorter wave length indicates that the eastern equatorial edge of the sun is approaching the observer with a velocity of 2 km/sec. and that therefore the sun rotates on its axis once in about 25 days.

A solar spectrum shows dark lines due to absorption by oxygen and water vapor in the earth's atmosphere. These atmospheric lines

are not displaced and thus may be distinguished from true solar lines. A spectrum of the impressive B group of atmospheric oxygen is reproduced in Plate 5, Figure 1. These lines coincide in the spectra of the east and west limbs while the solar lines are mutually displaced.

In the case of sun spots, it has made it possible to build up a picture of the motions of the surrounding vapors and to fathom the

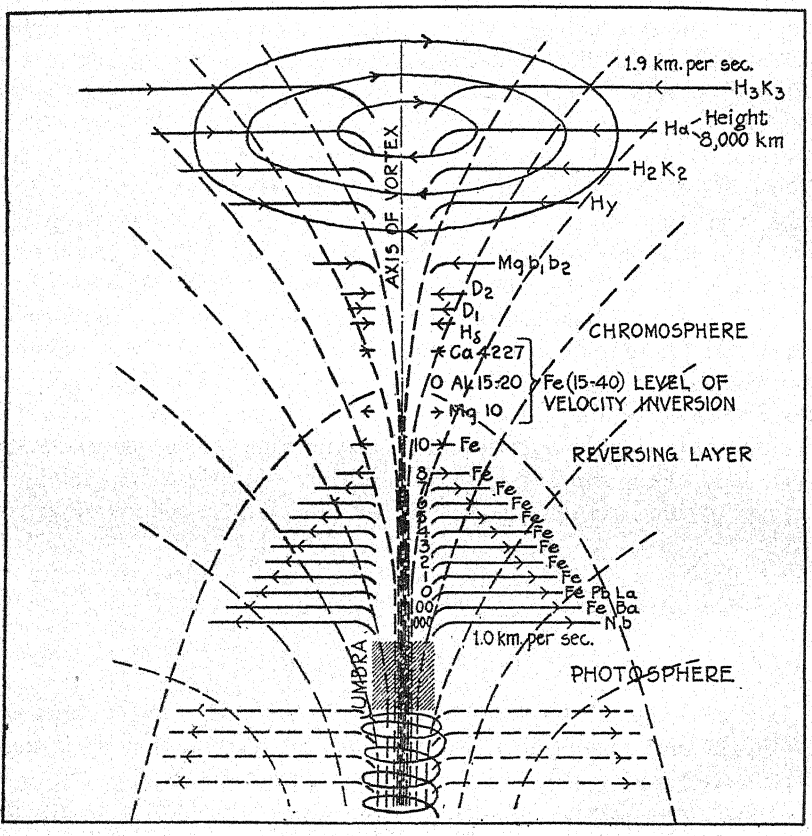



FIGURE 1.—Vertical section of a sun-spot vortex showing circulation of the gases at different heights and the lines of the magnetic field. To be considered in connection with the horizontal section of the high-level vortex photographed in the light from hydrogen at the height of 8,000 km. Plate 4.

sun's atmosphere. When the spectra of the centerward and the limbward edges of the penumbra of a sun spot suitably situated between the center and limb of the sun are photographed in juxtaposition, it was found by Evershed that for lines of moderate strength the two spectra are displaced, the one from the center edge toward the violet and the one from the limb edge toward the red (pl. 5, fig. 2). Interpreted as a Doppler effect, the displacement

means an outflow of the gases from the spot tangential to the sun's surface. An extensive series of observations at the Mount Wilson Observatory gave the data for a more complete analysis of the motions.

The results are graphically given in the accompanying diagram (fig. 1), which shows a vertical section of the surroundings of a spot, the axis of the vortex lying in the plane of the paper. Immediately above the shaded umbra, the gases in which the low-level lines of iron and those of the heavy elements originate are flowing outward with velocities proportional to the lengths of the heavy lines. At higher levels the velocity of outflow decreases and becomes zero for the strongest and highest-level lines of iron, the level of velocity-inversion lying at about 1,200 km. Above this level the motion is inward, the velocity increasing with height. The field-forming vortex is below the level of the umbra and in it the gases are rising as in a terrestrial tornado and spreading outward above the photosphere. The high-level chromosphere layers tend to settle, owing to the decreased pressure of radiation over the spot caused by the cooling of the expanding gases, and form a secondary vortex, in which the flow, as shown by Doppler displacement, is inward. The magnetic lines of force are indicated in the usual way as if diverging from the pole of a magnet. As seen from the earth in the red light of hydrogen the high-lying cyclone appears as in Plate 4, Figure 2, which pictures a horizontal cross section of it.

## ORIGIN OF FRAUNHOFER LINES

Spectrum lines are due to transitions between two energy states of an atom, the frequency of the emitted or absorbed radiation being exactly proportional to the difference in energy between the two states. Every absorption line is associated with the transition from one energy state to another of higher energy content and can only be produced when the atom is already excited to the lower energy state of the transition to which the line is due, measured by the excitation potential expressed in volts. The absorbed energy, $h\nu$, corresponding to the line is diffusely scattered or reradiated without change of wave length. This alone would give completely black lines, but the effect of collisions of the "second kind" is to supply radiation to the middle of the line so that none are completely black; this residual intensity is what makes the spectroheliogram possible.

## LEVELS

Lines in the solar spectrum give information of the conditions obtaining in the region of their origin. Like information concerning the conditions is given by lines originating in the same layer, but

the behavor of lines from different layers reveals characteristic differences. This is shown particularly well in studies of solar rotation and by the currents observed in the gases in the immediate neighborhood of spots.

*Correlations in level*

A. DATA FROM VARIOUS SOURCES

[Norm=linear velocity for lines of medium level]

| Lines | Rotation Obs.-Norm | Observers | Flow near spots | Heights |
|---|---|---|---|---|
| | *Km/sec.* | | *Km/sec.* | *Km* |
| $H_3$ and $K_3$ Ca+ | +0.20 | St. John and Ware | in 1.80 | 12,000 |
| Hα Hydrogen | +0.11 | Adams and Evershed | in 1.50 | 10,000 |
| 4226 Ca | +0.06 | Adams | in 0.06 | 2,100 |
| High-level Fe | +0.02 | Evershed | 0.00 | 1,200 |
| Medium-level Fe | 0.00 | Adams and Evershed | out 0.40 | 400 |
| 4196 La+ | −0.03 | Adams | out 0.75 | Low. |

B. SIMULTANEOUS OBSERVATIONS AT HIGH AND LOW LEVEL

| Lines | Equatorial velocity | Observers | Flow near spots | Heights |
|---|---|---|---|---|
| | *Km/sec.* | | *Km/sec.* | *Km* |
| 5172 and 5183 Mg | 2.03 | St. John and Ware | in 0.36 | 2,250 |
| 5165 and 5225 Fe | 1.95 | do | out 0.60 | 350 |
| $H_2$ and $K_2$ Ca+ | 2.12 | do | in 1.80 | 12,000 |
| Weak CN lines | 1.87 | do | out 0.63 | Low. |

When the linear equatorial velocity of rotation given by iron lines of medium intensity is taken for reference, the velocity given by Ca+ is 0.2 km/sec. greater, with lower velocities for Hα, Ca 4227, and high-level iron, corresponding to their separate and lower levels, the lowest velocity being given by lines originating immediately above the photosphere. The same arrangement of the levels is given by the flow near spots, high velocity inward, 1.80 km/sec. for Ca+, decreasing to zero for high-level Fe, and rising to maximum velocity outward for the lines of lowest level. A like correlation is shown by the heights taken from eclipse observations.

## CONSTITUTION OF THE SUN

The present view conceives it as a completely gaseous sphere. For the sun, built on the Eddington model, in which the radiation pressure is a constant fraction of the total pressure, the temperature at the center would be of the order of 29,000,000° K. The atoms in the interior are highly ionized, but are not destroyed or transformed into other elements, the only changes being the removal, more or less complete, of the orbital electrons. The mean molecular weight of the mixture of free electrons and nuclei is taken as 2.11. The pressure in the deepest interior, 36,000,000,000 atmospheres, is so

great that even at the high temperature the density is estimated to be approximately twenty-eight times that of water, though the mean density is only 1.4. The radiation pressure bears a very appreciable ratio to the weight of the superincumbent material.

The photosphere is a relatively thin gaseous shell, through which radiation from the interior does not pass directly, its optical opacity being due to its highly ionized state (Stewart). The temperature of its surface is approximately 6,000° K, and the pressure there a thousandth of an atmosphere. The total mass of the overlying gases according to Russell is approximately $10^{15}$ tons. The mass of the earth's atmosphere is three times as great, but on the sun the pressure (mass × solar gravity) is distributed over an area twelve thousand times greater. As the sun's atmosphere is approximately $10^2$ times as deep, its volume is $12\times10^5$ as large, hence its average density is extremely small, about $2\times10^{-11}$.

The reversing layer is a few hundred kilometers in thickness and contains all the elements found in the sun's atmosphere. In it the vast majority of the Fraunhofer lines originate. It is supported below mainly by gas pressure but above increasingly by the pressure of radiation. The reversing layer merges gradually into the chromosphere, which reaches 12,000–14,000 kilometers in height, and is supported by radiation pressure. The eclipse spectra of the chromosphere (pl. 3) show conspicuously the emission lines of the lighter gases, hydrogen and helium, and of ionized elements such as Ca+ and Ti+. The pressure at the top of the Ca+ atmosphere is of the order of $10^{-13}$ atmosphere (Milne) and at the photosphere $10^{-3}$ atmosphere (St. John and Babcock).

Prominences are luminous vapors, mainly hydrogen and ionized calcium, that often rise above the chromosphere to great heights, reaching at times to more than half the solar radius. (Pl. 6, fig. 1.) Formerly these were observed only at times of total eclipse of the sun, but now are photographed daily with the spectroheliograph. Their composition is known but there remains much to be explained as to the forces that originate and support them and control their movements. Dark masses of hydrogen are often photographed on the disk of the sun. (Pl. 6, fig. 2.) They were long suspected to be prominences seen in projection on the disk. This relation to prominences became clear through such fortunate observations as shown in Plate 7, Figure 1, where a dark hydrogen cloud was caught being carried off the disk by the sun's rotation and later in Plate 7, Figure 2, when completely off the disk and bright. The motions of both dark and bright hydrogen flocculi are now visually studied by means of the spectrohelioscope recently developed by Hale.

The corona gives a continuous spectrum in which absorption lines show faintly and upon which a bright line spectrum is superposed. The former is ascribed to reflected or scattered sunlight, the latter to an unidentified gaseous element considered formerly to be a hypothetical element, coronium, but now thought to be due to some known element peculiarly excited. The periodic table of the elements based upon atomic theory has no place for such a hypothetical gas. The recent identification by Bowen of the hypothetical nebulium lines with the "forbidden" lines of oxygen, nitrogen, and sulphur, whose production is favored by the extremely low density in nebulae, points to a similar explanation for coronium.

## RADIATION AND AGE OF THE SUN

The solar radiation at the mean distance of the earth from the sun is 1.94 calories per minute per square centimeter. It is subject to variation over the 11-year spot-cycle, being about 2 per cent above the mean when spots are most plentiful. Variations with periods of a few days may reach 3 per cent (Abbot). The total radiation from the sun is $38 \times 10^{32}$ ergs per second. Since pre-Cambrian times the sun has been radiating at approximately this rate. This implies a subatomic source of energy within the sun, the transformation of hydrogen into helium, the annihilation of matter (Jeans), or radioactive elements of higher atomic weight than uranium. In modern theory the output of solar energy is equivalent to a loss in mass of 4,200,000 tons per second. Even at this enormous rate it would require fifteen thousand billion years for the transformation into energy of a mass equal to that of the sun. The widely accepted value for the age of the earth derived from the radioactive content of the oldest rocks is of the order of sixteen hundred million years. On the assumption that the planets are the offspring of the sun's early years, a minimum age of two thousand million years is found for the sun (Nernst).

Recently Milne has rediscussed the internal structure of stars and finds that a star tends to generate a kind of "white dwarf" at its center surrounded by a gaseous distribution of more familiar type; the star being like the yolk in an egg. He concludes that in the intensely hot, intensely dense, nucleus, the temperatures and densities are high enough for the transformation of matter to take place with ease and that in this nucleus we must look for the origin of stellar energy.

## SCHEMATIC SECTION

A number of the factors bearing on the constitution of the solar atmosphere may be advantageously assembled in a schematized dia-

gram of a vertical section. (Fig. 2.) This represents the results of observation interpreted in accordance with the idea of levels of

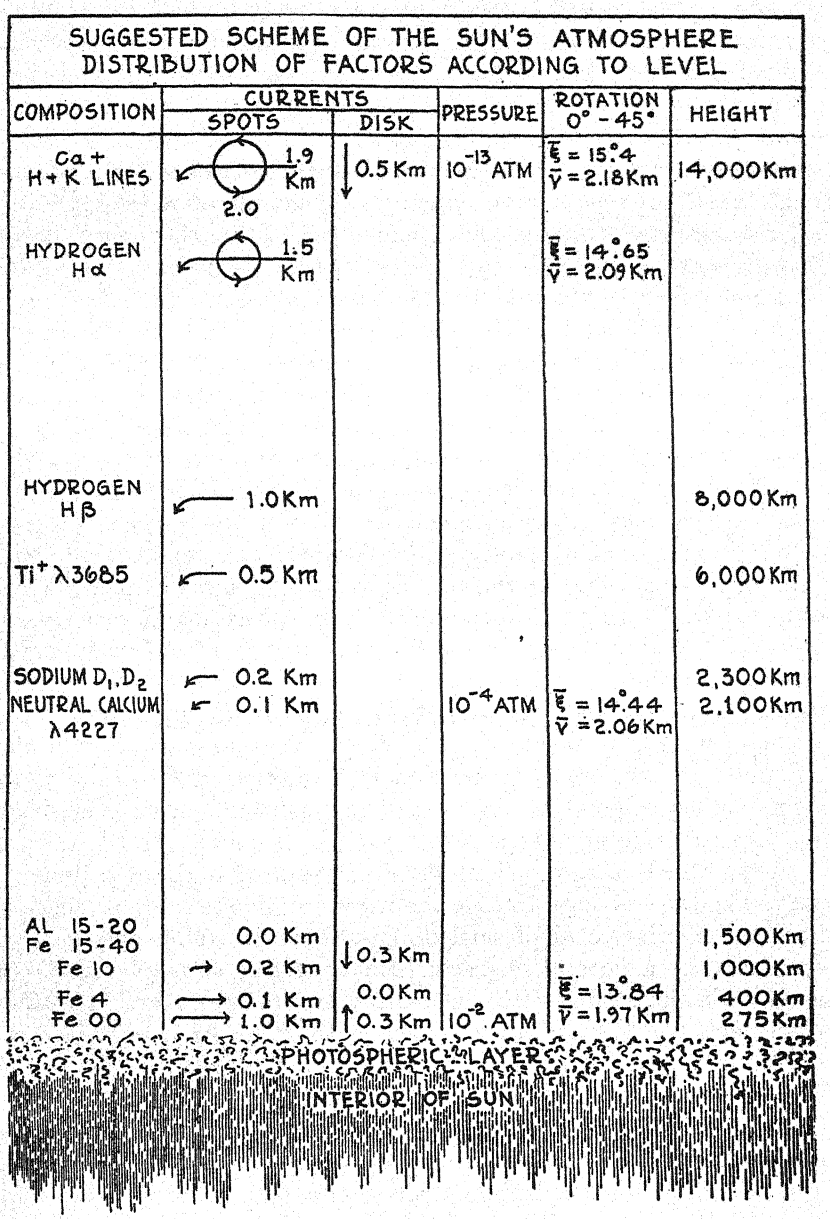



FIGURE 2

origin of Fraunhofer lines, an idea originally suggested by Lockyer and later introduced independently at Mount Wilson. The first column shows certain typical chemical components at various levels.

In sounding the sun's atmosphere from the outside, one would, on passing through the corona, encounter an atmosphere of ionized calcium; to this would be added at successively lower levels, hydrogen, ionized titanium, sodium, normal calcium, and then other elements in rapid succession until at the photospheric level all constituents would be present. Helium, probably because of its high excitation potential, does not appear as an absorption line in the solar spectrum, except over the more actively disturbed areas. It is prominent in eclipse spectra and extends to a height of 8,000 km.

In the second column, the cyclonic whirls in the upper chromosphere are indicated by circles. These secondary high-level vortices are probably called into existence through the low temperature of the underlying spot umbra, either as a result of the cooling of the lower chromosphere causing a down rush, or more directly as the result of a decrease in the radiation pressure by which the chromosphere is supported. As a rule, the direction of these high-level whirls corresponds in all sun-spot cycles to the terrestrial law, counter-clockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere. For the underlying vortices constituting the sun spots, the whirls are below the photosphere and their directions are unknown. Since the magnetic polarity is opposite in Northern and Southern Hemispheres, and reverses at each spot minimum, we may infer that change of polarity corresponds to change in the direction of the whirl in the field-forming vortex (Hale). The directions of the whirls in the upper and lower vortices are independent of each other. In the same column the length of the arrows is proportional to velocity of flow, and their directions correspond to the inward and outward motions at high and low levels, respectively.

In the third column (disk) displacements of high-level lines to the red and of low-level lines to the violet relative to lines of medium level, are similar to displacements that occur in stellar spectra and appear to be a general characteristic of stellar atmospheres, their magnitude increasing with the temperature of the star. The displacements for the sun are consistent with its position in the evolutionary sequence. As to the displacements of high-level lines to the red expressed in their equivalent (Doppler velocity in the third column of Figure 2), the following considerations offer a probable interpretation. The increase in width of H and K above 8,000 km indicates high ionic agitation. After emission, it is probable that some of these atoms will possess large outward velocities, and hence the next absorption will be from the violet side of the absorption line, where the radiation is much stronger than at the center. Consecutive emissions and absorptions will therefore endow these atoms with an increasing outward acceleration, and it is possible that some

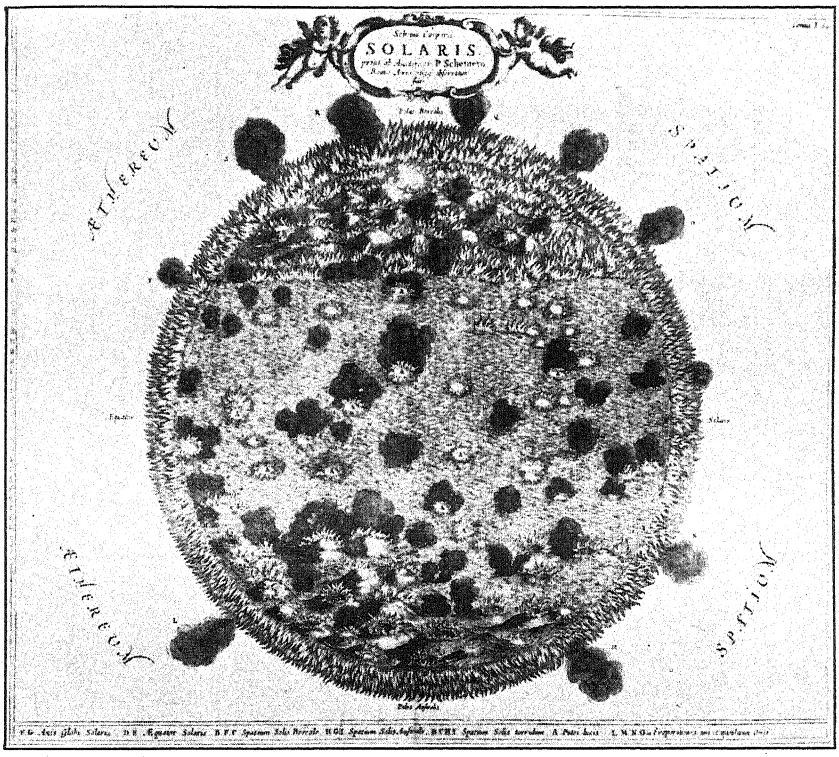
will eventually escape from the sun with enormous velocities. The velocities of descent are hardly likely to exceed the velocities of thermal agitation. When the Fraunhofer spectrum is observed, there are therefore more atoms absorbing from the red wing than from the violet. Hence the absorption line will appear displaced to the red, and this feature should become more prominent with increasing height (Milne, Merfield). The displacements to the violet at low levels seem explicable by the upward streaming of gases near the photosphere.

The last three columns show respectively the very low pressure in the sun's atmosphere by which the sun again shows its similarity to the stars, the rotation at different levels, and the heights to which the different gases rise as derived from the eclipse observations.

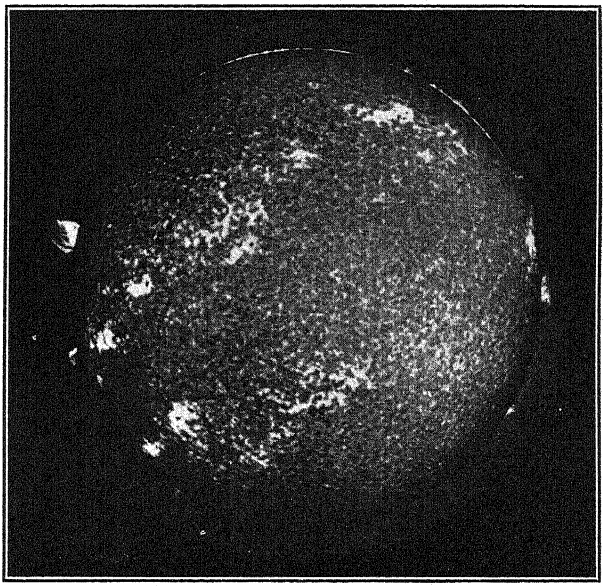
## RELATIVITY

The question of the gravitational displacement of the Fraunhofer lines predicted by the general theory of relativity has been a subject of extended investigation, with the result that when other known characteristic displacements in stellar atmospheres are taken into consideration the remaining displacements to the red universally observed are most satisfactorily interpreted in accordance with that theory (Evershed, St. John). The interpretation is reinforced by the observed effect in the "white dwarf" companion of Sirius by Adams and Moore.

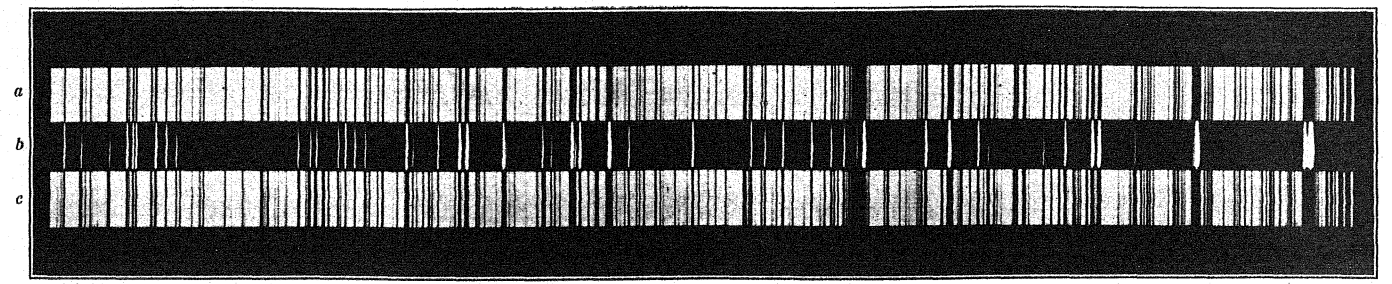
This brief outline of the progress in our understanding of the sun illustrates the wide-reaching results in astrophysical investigations from the union between spectroscopic observations on the sun, work in the physical laboratory, and deductions from atomic theory, and perhaps justifies the claim of astrophysics that it deals with the most interesting questions of physical research.




1. DRAWING BY KIRCHER AND SCHEINER, 1635, FROM THE COPY OF KIRCHER'S "MUNDUS SUBTERRANEOUS" (AMSTERDAM, 1678) IN THE LIBRARY OF MOUNT WILSON OBSERVATORY

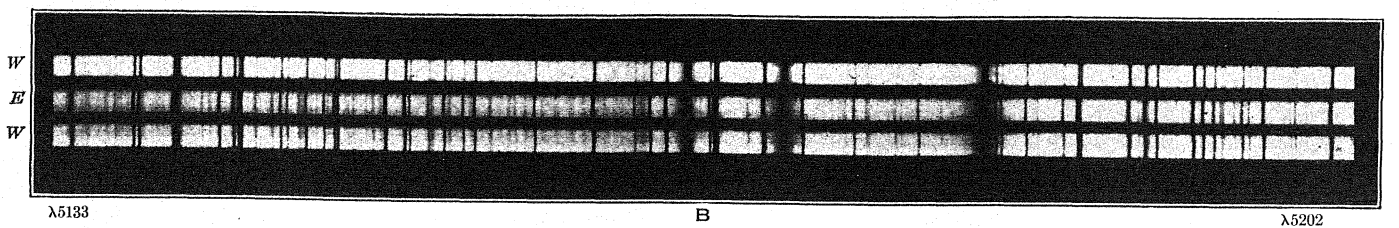


2. DISK OF SUN AND PROMINENCES FROM COMBINED SPECTROHELIOGRAMS IN THE K LIGHT OF CALCIUM, 1916

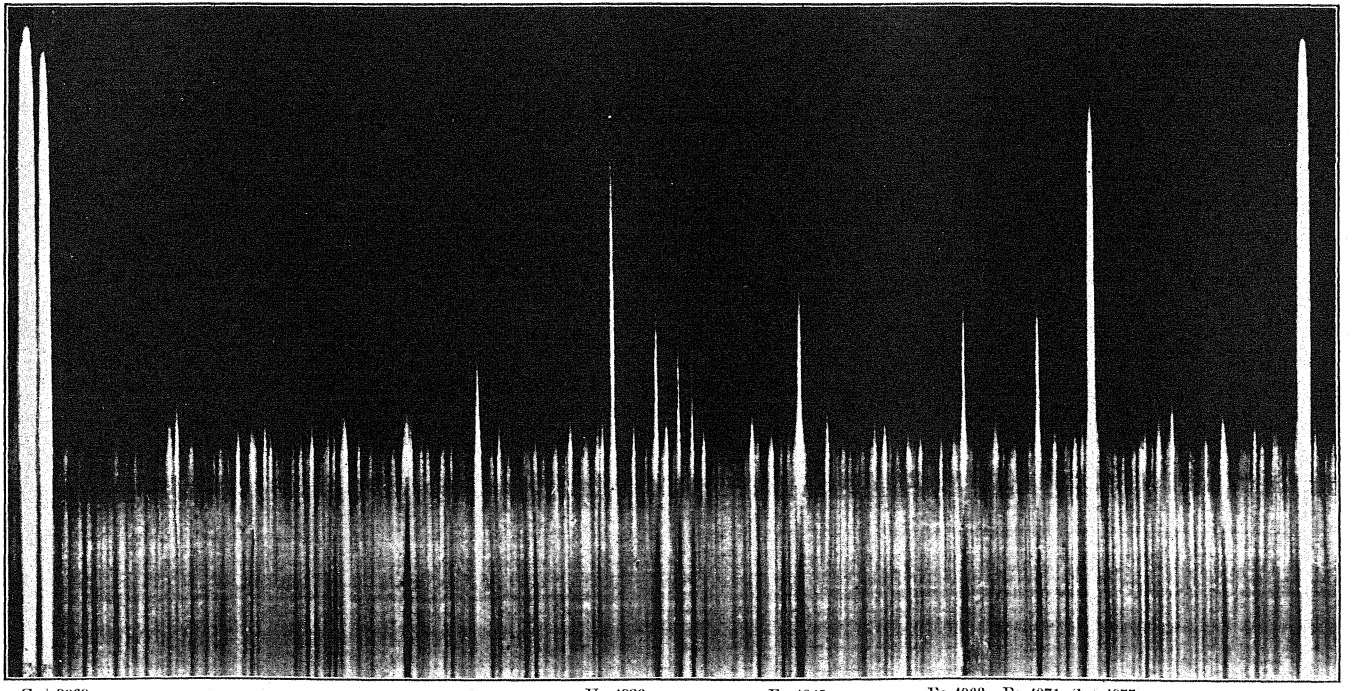



1. SPECTRA SHOWING THE IDENTIFICATION OF A FEW OF THE 3,288 SOLAR LINES DUE TO VAPOR OF IRON IN THE SUN'S ATMOSPHERE

*a*, Spectra of the sun; *b*, spectrum of iron vapor in the electric arc.

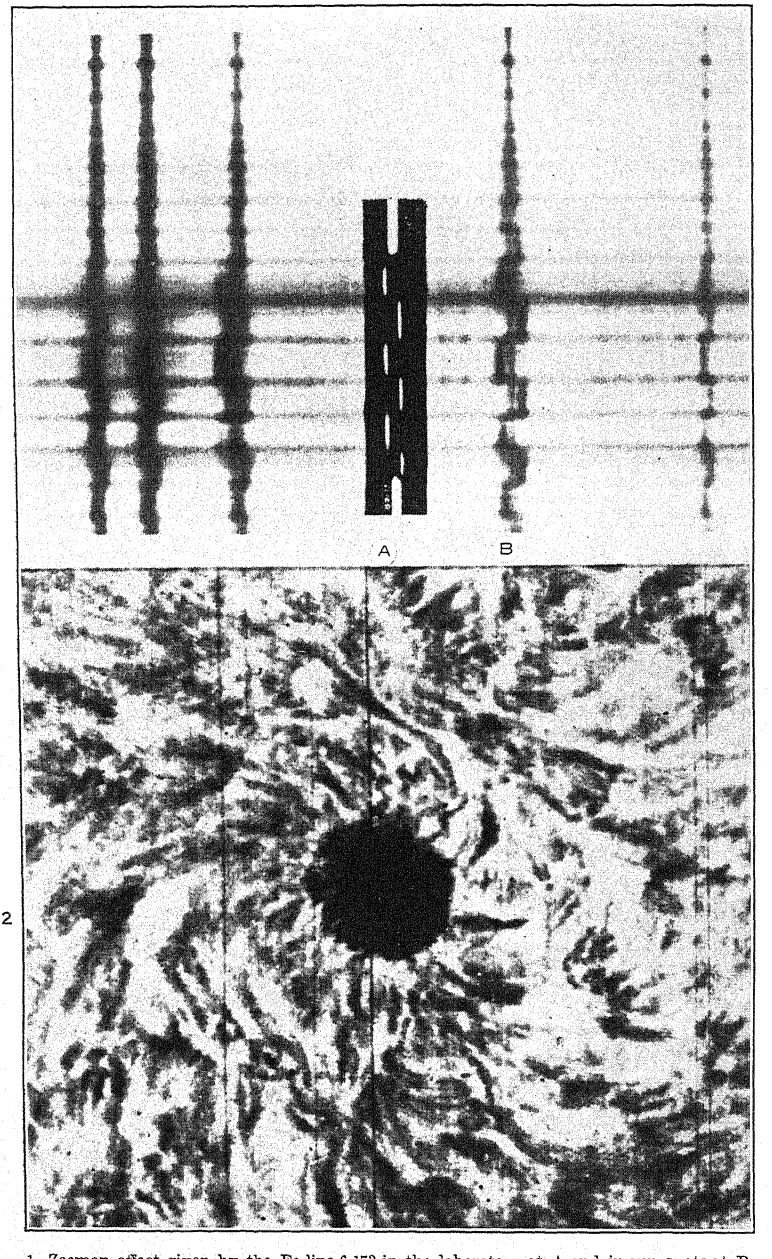



2. ROTATION OF THE SUN SHOWN BY THE OPPOSITE DISPLACEMENTS OF THE FRAUNHOFER LINES IN SPECTRA OF THE EAST AND WEST EDGES OF THE SUN'S DISK. TO THE VIOLET IN *E* AND TO THE RED IN *W*

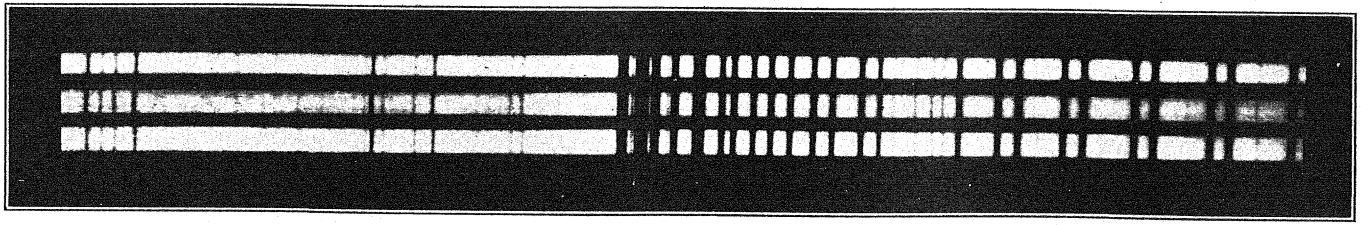



MOVING PLATE SPECTROGRAM BY W. W. CAMPBELL

Illustrating the great heights to which helium and ionized calcium and strontium rise in the chromosphere, compared with the strongest lines of neutral atoms like the iron triplet at λ4,045, λ4,063, λ4.071. The reversal of the absorption lines over the disk to emission lines in the flash is well shown by this triplet.

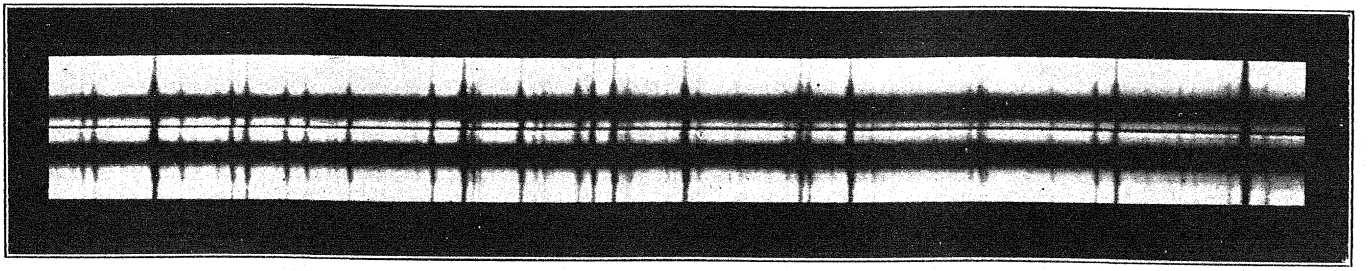



1. Zeeman effect given by the Fe line 6,173 in the laboratory at A and in sun spots at B. The line by which the magnetic fields in sun spots are usually measured. 2. Horizontal cross section of a high-level vortex photographed in the red light of hydrogen at a height of 8,000 kilometers. To be studied in connection with the vertical section, Figure 1 of text

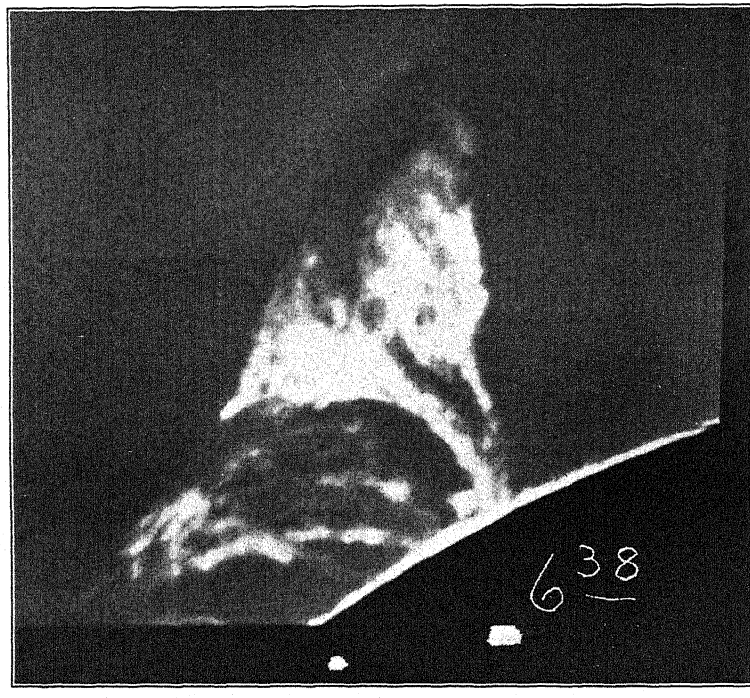


1. SOLAR LINES AND B GROUP OF ATMOSPHERIC OXYGEN

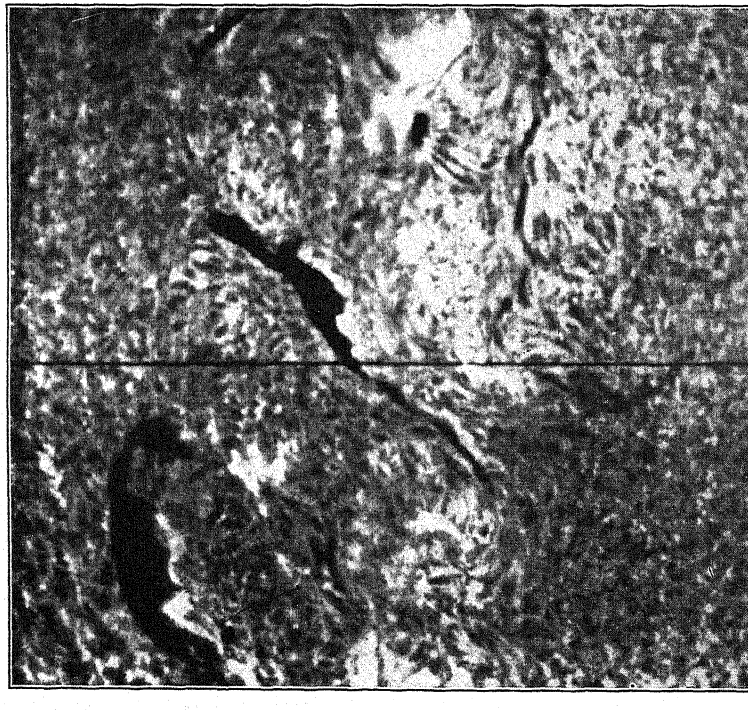
True solar lines are displaced in spectra of the two edges of the sun while those due to the earth's atmosphere are undisplaced.



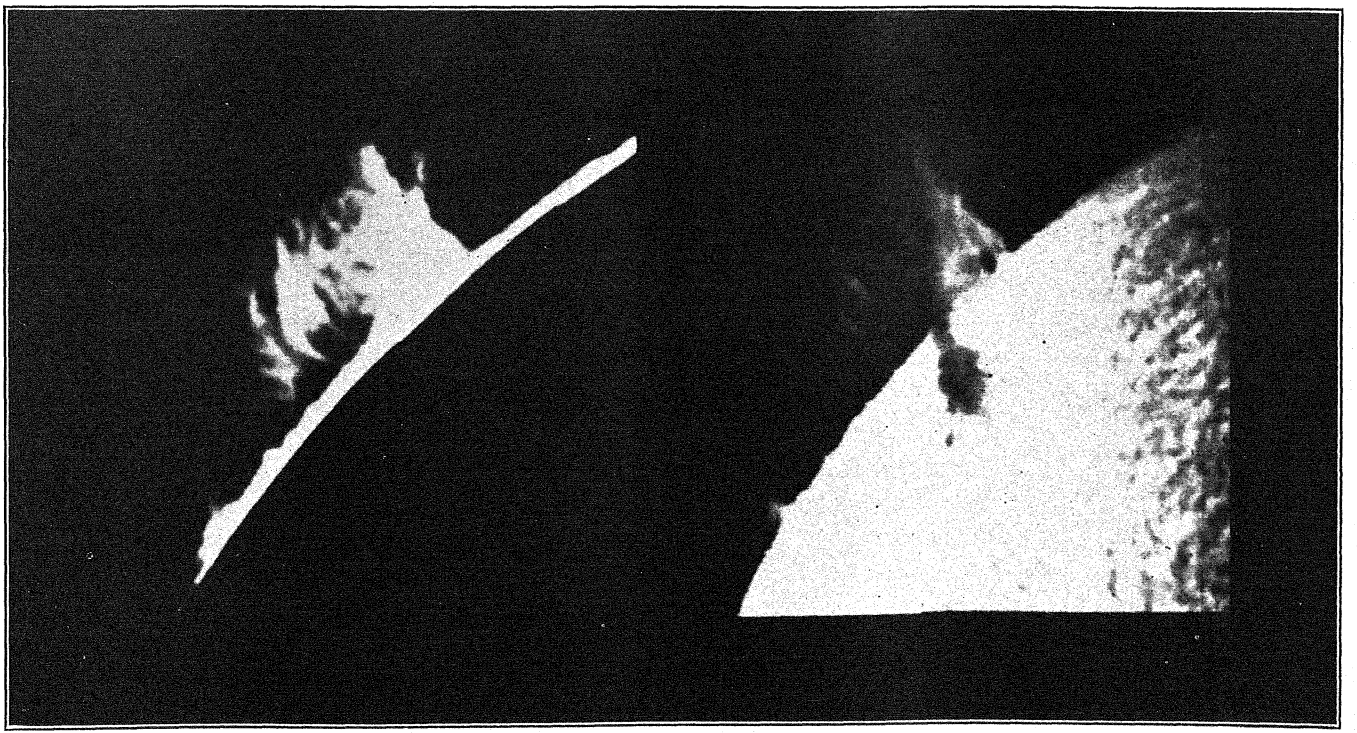
2. SPECTRA OF THE OUTER EDGES OF THE PENUMBRA OF A SUN SPOT




1. PROMINENCE 110,000 MILES HIGH. SPECTROHELIOGRAM IN Hα HYDROGEN



2. HYDROGEN CLOUDS DARK AGAINST THE HOTTER HYDROGEN BACKGROUND AT LOWER LEVEL



1

1. HYDROGEN CLOUD COMPLETELY OVER THE EDGE OF THE SUN AS A BRIGHT PROMINENCE

2

2. HYDROGEN CLOUD PARTLY ON AND PARTLY OFF THE SUN'S DISK

# THE MODERN SUN CULT[1]

By J. W. STURMER

*Dean of Science, Philadelphia College of Pharmacy and Science*

## SUN ENERGY

In the springtime all vegetation awakens to renewed life. This transformation would be most astonishing if its annual recurrence had not taught us to accept it as a matter of course. The advent of the growing season which comes with unfailing regularity, is the result of more sun energy, that is, more light, and with it, more heat rays which we can feel yet can not see, and more, also, of that mysterious radiation which we can neither feel nor see, but which we now know to be a potent agency affecting all living creatures, namely the ultra-violet rays.

Our house plants have the habit of growing toward the sun, and we ourselves intuitively seek its light and warming rays. No physician need order us to do it; it is simply natural that we crave sunshine. Under its influence we are alert, active, optimistic, cheerful. When great lowering clouds hide the sun from us, we are apathetic, lethargic, and gloomy. "Diogenes," asked Alexander the Great, "what can I do for you?" "What boon would you beg of the all-powerful conqueror of nations?" "Step aside, Alexander," answered the old philosopher, who was not noted for tact or courtesy. "Step aside, and do not shut out my sunlight."

## WINDOWS OF GLASS AFFECTING HEALTH

Primitive man was at one time a cave dweller. His house was dark. There were no windows. But the chances are that he was at home but little, that he lived largely in the open, and that only when the weather was extremely inclement did he take refuge in the dark hole in the rock which he called home. It is highly probable also that when the season permitted it, his apparel was not more extensive than a modern sun suit. We may be sure that he got his ultra-violet pretty generously, as did also his spouse and children. Unquestionably man is an out-of-door creature intended to live in the sunlight.

[1] One of a series of popular science lectures given at the Philadelphia College of Pharmacy and Science, 1929 season. Reprinted by permission from the American Journal of Pharmacy, vol. 102, No. 2, February, 1930.

And for thousands of years he so lived. But a few centuries ago a marvelous transparent substance was discovered, namely glass, and this discovery has in a marked degree changed the human habits of life and of work, for the cold months are now spent largely indoors, behind this glass, which shuts out the wintry winds, but transmits sunlight, and with it some of the warmth of winter sunshine. Unfortunately, however, and this was unknown until quite recently, glass does not transmit all the kinds of sun energy which we need, for the rays of shorter wave lengths than those of light are in large measure intercepted by glass and so these rays now fail to reach us. Thus we receive in our homes, and even on our sun porch, a vitiated and abnormal sun radiation—a radiation which has lost something, something imperceptible to our organs of vision, but which we require for our physical well-being.

## EFFECTS OF SUN ACTIVITY

The sun is about 93,000,000 miles distant. Its enormous mass exhibits tremendous chemical activity, and it is radiating its substance—so scientists inform us—at the rate of several million tons per second. The sun radiation thus engendered streams into space and only a relatively small per cent of it reaches the planet on which we live. Yet, as this small portion of the total varies, we experience winter or summer, great heat or extreme cold; our vegetation flourishes or dies; our hills are green, or they are white with a covering of water crystals from the skies; our continent experiences a glacial period, or an age of tropical warmth.

The sun radiation vaporizes the waters on the earth and forms clouds, fog and rain. It stirs up the atmospheric mantle which surrounds our planet and causes winds to blow—gentle spring zephyrs, or devastating tornadoes. It develops the green and the yellow pigments in leaves and the riot of colors in flowers. It also makes the vegetable cell function as a chemical laboratory in which water and the carbon dioxide of the air form plant substance, and thus our plants grow, producing our food, our shelter, and our raiment. Even our fuels, gas, coal, and oil, have a sun-energy origin, and the modern cliff dweller in his steam-heated apartment, reading his newspaper under the incandescent Madza, gets light which originated in the sun, no matter whether the electric current he uses is generated from coal or by water power. We are warmed by the sun, fed by the sun, and clothed by it, just as was primitive man, ages before us.

## WHAT IS SUN ENERGY?

Now what is it that the sun sends to us through 93,000,000 miles of space? Is it a stream of electrons? So it would appear. But

we had better not be dogmatic on this subject which is linked with the fundamental concepts of energy and matter—concepts which have been modified quite recently, and may soon be modified still further. Most physicists now subscribe to the corpuscular theory, in accordance with which light, and the ultra-violet and the heat rays as well, come from the sun as a stream of corpuscles, emitted in a succession of bursts, but the latter so close together, and following one upon the other with such inconceivable speed, that the stream is, as far as we can perceive, continuous and unbroken.

### WAVE LENGTHS

When, however, solar radiations are to be dealt with in their practical aspects, as for instance in regard to reflection or refraction, it is the other theory of light, the wave theory, that provides the nomenclature. So we continue to speak of wave lengths, and of wave frequencies, just as we do in radio parlance. Indeed, it is generally accepted that certain light waves may be " tuned in," and other light waves refused entry. On this basis we explain the phenomenon of color. But to understand the explanation we must remember that the light waves of the different colors of the spectrum differ in length; that the red waves are the longest, and that the waves become shorter and shorter, through the orange, yellow, green, blue, and violet, the latter being less than half the length of the red.

### ULTRA-VIOLET

It must not be assumed that ultra-violet rays are of a single wave length. On the contrary, they embody a range of wave lengths, just as light rays represent a range. The longest waves of ultra-violet are just a little shorter than the shortest violet waves. They are thus just beyond the violet rays of the spectrum. Hence the term ultra-violet. It is not quite correct, however, to speak of ultra-violet light, for light is visible, while the rays of shorter wave lengths than those of light are invisible. Hence we had better use the term ultra-violet radiation.

### THE ÅNGSTRÖM UNIT

We must bear in mind that the waves of light rays are exceedingly minute—too short to be measured by ordinary methods, and that we can not conveniently express such infinitesimal lengths in fractions of inches or even of millimeters. And as the waves of ultra-violet rays are shorter still, the necessity for a special unit of length to be employed in the measurement of such minute waves is obvious.

The unit most generally used is called the Ångström unit, and was so named in honor of a Swedish physicist by the name of Ångström.

It is a metric unit, and represents $\frac{1}{10000000}$ of a millimeter, the millimeter being equivalent to about $\frac{1}{25}$ of an inch. Now in terms of this unit visible light ranges from about 3,600 Ångström units (Å), to about 7,700 Å—although it must be remembered that the human organs of vision vary in their range, and that many persons can not see the rays of wave lengths as short as 3,600 Å, nor those of wave lengths as long as 7,700 Å.

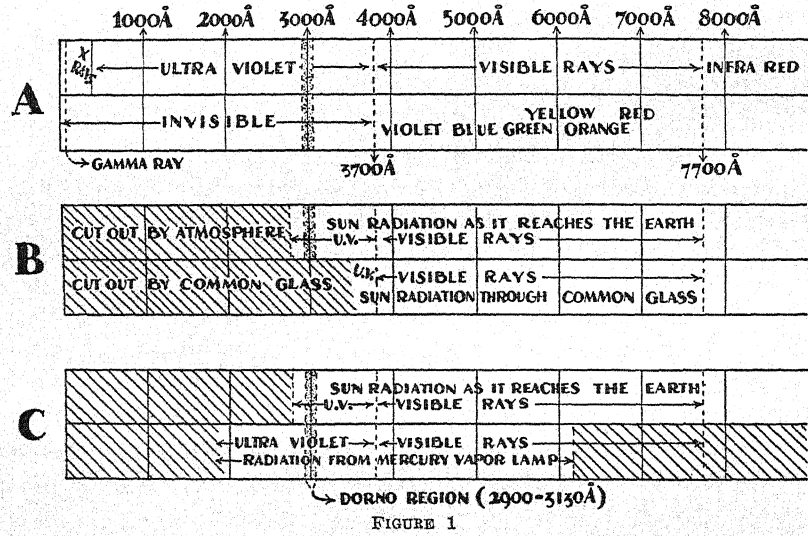



FIGURE 1

WAVE LENGTHS OF ULTRA-VIOLET

Wave lengths shorter than 3,600 Å, and down to about 1,000 Å, constitute the ultra-violet radiation. The shorter the waves, the higher the frequency, that is, the larger is the number which pass a given point in a unit of time. All solar radiation travels at the same inconceivable speed of about 186,500 miles a second, thus being capable of encircling the earth more than seven times in that short period. This applies to ultra-violet as well as to visible light, just as it does also to the very long waves which carry our radio programs. This means that the rays from ultra-violet lamps reach us so speedily—if they are not absorbed by an intervening medium—that we have no time to side-step them, even though we may stand at some distance from the lamp. We can protect ourselves only by the use of an intercepting medium.

The radio waves, many city blocks in length, the infra-red, visible light, ultra-violet, and X rays, all seem to be fundamentally the same, except in the matter of wave lengths and conversely in the rapidity with which the waves follow one upon the other; but by

virtue of this variation they exhibit a most decided difference in penetrability and in their action on inanimate objects and on living organisms.

### SOURCE OF ULTRA-VIOLET

An ordinary wood or coal fire emits light and heat rays, but no appreciable ultra-violet radiation. If, however, carbon disulphide is burned in a stream of oxygen, the flame which exhibits intense white light, emits also ultra-violet radiation. So ordinary combustion can be the source of these mysterious rays. But carbon disulphide is a substance both dangerous and malodorous, and its use in lamps for the production of ultra-violet is limited to laboratory experiments.

### ULTRA-VIOLET LAMPS

The practical ultra-violet lamps are types of electric lamps. This applies to those which are used for strictly scientific purposes as well as to the lamps now so largely sold for family use for the irradiation of the human body. To be sure, the lamps for scientific purposes are designed to furnish a greater intensity of radiation, and one embodying a wider range of wave lengths. They are also provided with filters to intercept the light waves, which is not a necessity if the lamp is to be employed for therapeutic purposes, as for such uses the accompanying light waves seem to be desirable and certainly not objectionable.

Structurally the lamps may be divided into two classes: The exposed arc lights, and the lamps in which the radiation is produced within a bulb or tube. The principle upon which the majority of ultra-violet lamps are constructed is that an electric spark sent through the vapor of certain metals—iron, nickel, zinc, mercury, etc.—produces this radiation.

A common form of the arc type has carbon electrodes with metallic cores, or cores impregnated with metallic ingredients. But also carbons without metallic ingredients may be used, in which case a very wide arc (about 2 inches) is employed.

The other kind of lamp (always with a bulb or tube) is known as a mercury vapor lamp. Such a lamp may have electrodes of mercury, or these may be of some other metal, such as tungsten; but in either case the gap between the electrodes is occupied by mercury vapor which the current traverses and causes to glow with a greenish light, the invisible ultra-violet rays being produced with the light waves. The light from such a lamp does not include the longest visible waves, that is, it is devoid of the red and orange; and as a consequence the light is colored, for white is obtained when all the wave-lengths of the red, orange, yellow, green, blue, and violet are produced. The

lamps used for therapeutic purposes may be arc lamps or mercury vapor lamps, but for scientific use the latter type of lamp is usually preferred.

A common form of mercury vapor lamp is essentially a specially constructed quartz tube, exhausted of air, and containing liquid mercury which may be made to separate, and thus an arc may be struck. The wires are connected in such a manner that the spark must jump from the one body of mercury to the other, thus traversing the gap occupied by mercury vapor.

Quartz is employed for the tube or bulb because of its remarkable transparency to ultra-violet rays, permitting penetration of wave lengths as short as about 1,850 Å. Only calcite and fluorspar are known to transmit yet shorter wave lengths. For the lamps designed for therapeutic use, quartz need not be employed, as such lamps are planned to furnish only the ultra-violet rays of wave lengths greater than 2,900 Å, these being the rays which come to us in sunshine. Thus a special kind of glass may be made to serve for the tube or bulbs, and the employment of quartz is not necessary for family sun lamps. Lamps embodying bulbs or tubes are known to become less efficient with use. This progressive loss of efficiency is largely due to changes which the radiation effects in the quartz or glass, probably a gradual devitrification, and a discoloration because of the deposition of particles by sublimation.

### FILTERING OUT LIGHT WAVES

The filters used to cut out the light waves, so that only the ultra-violet may be transmitted, are either plates of quartz on which a thin film of silver has been deposited, or they are glasses deeply colored with certain metallic ingredients.

### THE INVISIBLE BECOMES VISIBLE

When the invisible ultra-violet rays, unaccompanied by light rays, are caused to fall upon certain objects, an astonishing phenomenon may be observed. Objects which in common light have color, may change color; and objects which are commonly colorless, may exhibit color—may show red, orange, yellow, green, blue, or violet—any color of the spectrum. Thus, the fingernails, the teeth, and the eyeballs glow with a pale yellow light. A crystal of calcite looks like a coal of fire; a crystal of fluorite shows a beautiful violet blue. The zinc ore called Willemite, glows brilliantly with a yellow-green light. Indeed, many chemicals, in ultra-violet light, show characteristic color effects. Thus, calomel exhibits a brick-red color, sodium salicylate is violet blue; quinine, violet; petrolatum,

light blue. The explanation of such extraordinary effects is that these substances, and many others which show color under ultra-violet have the property of reducing the latter radiation to longer wave lengths effecting a step-down, as we might call it, and thus bringing the rays within the range of the visible spectrum.

## FLUORESCENCE

This phenomenon is called fluorescence, because it was observed first in the mineral fluorite.

Not only the color, but also the intensity of the fluorescence, varies greatly. Thus, for example, both sodium and potassium salicylate show a violet-blue; but the fluorescence of the sodium salt is much more pronounced. Again some solids which show little or no fluorescence, may develop it to a marked degree when they are dissolved in an appropriate solvent. The examination of substances under ultra-violet is a new development in science, and one which gives promise of many applications in solving problems in practical chemistry.

Certain substances fluoresce with a red light, that is to say, they step down the invisible rays to about 7,000 Å. If the waves coming from the chemical when it is subjected to ultra-violet are mostly waves of about 5,500 Å, these will appear to our eyes as green; and so on through the range of colors which are seen in the rainbow. But we must remember that just as visible light represents not a single wave length but a range from about 7,700 Å to about 3,600 Å, so does ultra-violet radiation represent a range of wave lengths, beginning where the shortest waves of the visible spectrum end, at about 3,600 Å, and diminishing in length to about 1,000 Å. Immediately beyond the ultra-violet there lies an unexplored field; and then, farther on, in the neighborhood of 100 Å there are the X rays concerning which we have some definite knowledge. And, lastly, beyond the X rays, come the shortest waves known to science, the gamma rays, from radium, and beyond these the cosmic rays about which we now are receiving rather startling information.

## ABSORPTION OF ULTRA-VIOLET

We are all familiar with the fact that some substances, like soot, absorb all the rays of common light, and hence appear black, while other substances reflect indiscriminately all the wave lengths of light, as does this paper, and hence appear white. We know also that many substances exhibit selective absorption, failing to appropriate the red, the yellow, the green, or the blue, and thus possess the colors of the wave lengths which are not absorbed.

Now ultra-violet, speaking generally, is much less penetrating than the longer waves which we can see, and this feeble penetrability diminishes more and more as the wave decreases in length. The opacity of most known substances to the ultra-violet radiation has tended to make its study difficult, and it was not until the technique of making quartz glass had been perfected that much headway could be made. But in fused quartz we have a medium transparent to waves as short as 1,850 Å. For the study of still shorter waves certain minerals, namely fluorite and calcite, are employed. But the waves shorter than 1,850 Å have at present no practical application, so the quartz glass serves very acceptably.

## THE WAVE LENGTHS WHICH PASS THROUGH THE ATMOSPHERE

Solar radiation is rich in ultra-violet. Just how rich, and what its range of wave lengths may be, we do not know, perhaps shall never know, for our atmosphere, even when it is clear, cuts out all the wave lengths shorter than those of about 2,900 Å. What is known concerning the shorter waves has been learned through the study of radiation artificially supplied by arc lights and lights from sparks through metallic vapors.

## ULTRA-VIOLET THROUGH GLASS

Common glass transmits only the longest waves of ultra-violet radiation, those which are longer than about 3,400 Å, and hence are in the neighborhood of the visible violet light waves. This explains why a sunporch furnishes impoverished sunlight. But in recent years special kinds of glass have been made, designed to transmit the solar ultra-violet more generously. The claim is made that this glass transmits about 65 per cent of the invisible active rays, a statement which requires explanation. The facts are these: Not 65 per cent of all the ultra-violet waves of sunshine pass through in the same proportion in which they occur out of doors, but rather 65 per cent of the radiation, with a much greater absorption of the shorter waves—even a total absorption of some of them—and a lesser interception of the longer ones. In other words, these so-called ultra-violet transmitting media do cut out an appreciable amount of the wave lengths shorter than about 3,000 Å.

## THE DORNO REGION

The significance of the interception of wave lengths shorter than about 3,000 Å by the special glasses, and of all wave lengths below 3,300 or 3,400 Å by common glass is better understood when it is known that the rays which produce the beneficial effects on the

human skin connected with the production of vitamin D are those of wave lengths from 2,900 Å to 3,130 Å. This region of the ultra-violet range of wave lengths is known as the Dorno region, and embodies the rays used therapeutically. These are the rays which are desired chiefly also in the radiation from the ultra-violet lamp. Rays of wave lengths from 2,800 Å to 3,300 Å are known to produce pigment, but particularly is this effect said to be due to the wave lengths of the Dorno region. It appears that tanning is nature's protection against too much ultra-violet radiation of the wave lengths which cause the chemical changes in the skin, for when the tan has become deep enough, the Dorno rays no longer penetrate, but are absorbed by the pigment and changed to heat rays.

### WINDOWS

Window panes of quartz glass, $SiO_2$ give, of course, the best results in the transmission of the ultra-violet of the Dorno region; but only quite recently has the manufacture of quartz window panes been placed on an industrial basis, and unfortunately the price is still too high to admit of their general employment in the windows of solaria. The other types of ultra-violet transmitting glass, though not as satisfactory, are much cheaper. A still cheaper substitute is celophane, which is essentially a transparent product of cellulose. This substance transmits the radiation quite well, but it lacks durability, and requires a specially constructed frame.

### DOSAGE OF SUNSHINE

How much sunshine do we need? Sunshine, like heat, food, or medicine, or any other agency which affects us, must be taken in proper apportionment. There is such a thing as too much food. Certainly, such a thing as too much calomel. That too much heat hurts us, we learn in early childhood. Sooner or later we learn also that too much sunshine is harmful. And an extensive and deep sunburn is not only painful, but like any other burn, is dangerous, resulting in cell destruction, with the generation of toxins, which cause systemic poisoning. Thus even sunshine must be taken in proper dosage. Fortunately, however, sunshine does not ordinarily harm us if we accustom ourselves to it gradually, and thus avoid sunburn. This remark, however, applies only to persons who are well, for in certain diseases even strong sunshine may be detrimental.

### PROTECTION AGAINST ULTRA-VIOLET

If we are interested in protection against ultra-violet rather than in its transmission, we need but remember that substances which allow only the longer waves of the visible spectrum to pass—amber

glass, red glass, orange, and yellow glass—will prove opaque to ultra-violet, while a medium which cuts out the red end of the spectrum and transmits the violet and blue will prove to be rather transparent also to the adjacent invisible waves just beyond the violet. Thus blue cobalt glass transmits some ultra-violet, while red glass and amber glass filter it out, together with the short-wave radiation of the visible spectrum, namely, the violet, blue, and green.

It will be seen, in the light of this fact, that the practice, formerly in vogue, of keeping the light-sensitive chemicals in blue glass bottles was a misguided procedure, destined to prove ineffectual, while our present-day practice of employing amber glass is founded on sound principles and is much more effective.

Another means employed to shut out ultra-violet is to interpose a fluorescent substance as a protective, for such a substance will transform this radiation into visible light waves. The cold creams and ointments specially devised to protect against sunburn are compounded on this principle and contain fluorescent material. Even the ointment bases are fluorescent.

That sunlight deleteriously affects house paint is well known, and we have all observed how much longer paint lasts on the north side than it does on the southward exposure. The inclusion of a fluorescent material is, therefore, of benefit in house paint. Now zinc white is such a substance, and its employment in the paint materially lowers the penetration of the ultra-violet rays which are so destructive to the linseed-oil binder, causing the oxidized oil to disintegrate to powder, thus bringing about the result which the painter refers to as "chalking." Most face paint, also, is somewhat fluorescent, and is to some degree a protection against sunburn.

## CLOTHING AND ULTRA-VIOLET

A few remarks about clothing may be relevant in this discussion. A person exposed to the ultra-violet in connection with electric welding may receive a burn through his clothing. This is due to the intensity of the radiation. But most clothing effectively intercepts the light rays and also the ultra-violet radiation of sunlight. Animal hair is quite opaque to solar ultra-violet. Only very white hair transmits it to a slight extent. This means that all woolen clothing is an effective ultra-violet filter, and that the modern male promenading on the boardwalk receives practically no such radiation through his clothing. Silk also is fairly opaque, linen a trifle less so, whole cotton is a bit more transparent. The most transparent textile is a loosely-woven rayon or artificial silk, which explains why the sex known during the Victorian era as the weaker sex is on the way to becoming the robust sex. The girls

are getting more solar radiation, hence more vitamin D. This in part explains it. I would not be guilty of a breach in tact and criticize feminine raiment, which by the way would be futile, for I know that in the past neither the facts disclosed by science nor the admonitions of the medical profession have had any influence on the fashions of dress. Hence it is probably fortunate that I have warrant for the statement that the feminine dress of to-day is in far closer harmony with the newer facts pertaining to irradiation as a health measure than is the modern attire of the male. Women have gone far, since Civil War days, in so changing the fashions as to provide for plenty of sun irradiation; and in this span of time the men, alas, have made progress merely to the extent of having shaved off their whiskers and exposing their chins to the sun. Only on the beach at the seashore does the pipe-smoking sex get an even break when it comes to solar radiation. What should be done about this is a matter far beyond the scope of this discussion. We give it up.

### SUSCEPTIBILITY TO SUNBURN

The human skin varies considerably in its tolerance of solar radiation. Light-skinned persons are more sensitive to it than are the dark skinned, and in most individuals a tolerance may be slowly developed by progressively increasing doses—if one may use the term doses in this connection. Speaking generally, our arms can stand about half again as much as the chest, abdomen, or back; the legs a little more than the arms, the backs of our hands about 5 times as much, and the palms about 15 times as much, while the foot soles are most resistive, because here the skin is thickest, and the outer skin is a poor conductor of radiation. But persons who do not tan must be very careful in taking sun baths.

### BURNS BY REFLECTED RAYS

A sunburn, unlike a heat burn, does not become manifest instantly. We may receive an overdose of sun radiation and remain oblivious of the fact for three or four hours. Nor is it easy to judge how long we may with impunity subject ourselves to sunshine at any given time, for so much depends upon the time of day, the season of the year, and the atmospheric conditions. We should know, however, that not only the direct rays burn, but that diffused sunlight, and reflected radiation, does also; that, for example, we may sit in a boat under an awning and receive a burn. It should be borne in mind that much of our ultra-violet comes to us reflected from the sky, and that the north exposure of our house provides about half as much as the exposure facing the sun.

## VARYING INTENSITY OF SUNLIGHT

It may, further, help us to guard against sunburn if we remember the fundamental fact that the lower strata of our atmosphere are particularly absorptive toward ultra-violet, much more so than the more rarified strata higher up, the curve of ultra-violet in sunshine being virtually identical with the arc described by the sun in its course from horizon to horizon, which explains why old Sol is so much more powerful near the middle of the day, and much feebler when in the morning and evening its rays travel a longer distance through denser strata. It is indeed a common observation that at sunrise and at sunset even the violet and blue of the visible spectrum is largely cut out, giving us a preponderance of reddish and orange light. And as a matter of fact, the ultra-violet is almost wholly intercepted at the same time.

## WINTER SUNSHINE

In the winter, the sun is not so high in the sky, and its slanting rays are for this reason relatively poor in ultra-violet, just as are those of the morning and evening sun. Furthermore, there may be fog, clouds, and soot particles, all of which filter out the shorter rays. Soot is the greatest offender in this respect, and does much to deplete still further the enfeebled sunshine of the cold season of the year. Our industrial centers naturally suffer most in the matter of vitiated sunlight, for in order that we may keep warm, and that our wheels of industry may be kept spinning, immense quantities of soot are belched forth from our chimneys.

## DEFICIENCY OF ULTRA-VIOLET

In other words, we are systematically sacrificing the short-wave solar ultra-violet in order that we may have an abundance of the longer waves which keep us warm. Only in very recent years have we learned about the unhealthfulness of this practice, and have come to the conviction that something must be done about it. A paucity of solar radiation means, so medical men tell us, a slackened metabolism, an enfeebled condition, a lowered resistance to germ diseases. It has in fact been suggested that the gradual extinction of certain Indian tribes may be due largely to their altered dress, and their changed modes of life, resulting in inadequate sun irradiation, which is so necessary to them. In children, regardless of race, too little sunlight may mean rickets, or tuberculosis; and it was indeed in the treatment of these diseases that solar radiation was first employed in a systematic way. The sun cure is not, however, in reality modern, for Antyllus, a physician of ancient Rome, made use

of it, and he practiced heliotherapy long before anything was known about vitamin D. It is interesting to know also that rickets is the disease which he treated with sunlight. But since his day much definite information has been brought to light, some of it by feeding experiments conducted with animals, both in the absence and in the presence of radiation. Curative procedures also have been engaged in, experimentally on animals, and clinically on patients in hospitals.

### VITAMIN D

It is now known that when the skin is irradiated with ultra-violet, pigmentation or tanning is not the only result. Far more important is the change experienced by a certain chemical substance in the skin, a substance which becomes activated to form a vitamin, namely, the vitamin now designated as vitamin D, which appears to be just as essential to the proper functioning of the human organism as is certain mineral matter which, it is well known, we must supply in our diet. If, then, we receive, because of our abnormal modern conditions of life, too little sun radiation, the tiny laboratories in our skin fail to elaborate an adequate supply of vitamin D, and as a result, the life functions fail to go on normally and as they should, even though we may not develop a recognizable disease.

### BOTTLED SUNSHINE

We may in such cases proceed in a manner suggested by the serum treatments. We may obtain from another living organism the substance which we fail to produce ourselves. If we cannot develop our own vitamin D, we may buy it, and take it as medicine or food. Now the codfish, and other fish also, possess an abundance of vitamin D, the source of which appears to be the marine algae, which are eaten by shrimp and small fish, which in turn supply the vitamin much against their will to the larger fish. The vitamin D in fish is found principally in the liver, and it occurs in the oil expressed from fish liver. So cod-liver oil has come to be known as "bottled sunshine" useful in the treatment of the diseases which develop because of an inadequacy of solar radiation.

### HOW MUCH SUNSHINE IS ENOUGH

But what amount of such radiation and how much ultra-violet is adequate? We do not know. Physicians recognize the diseased conditions which follow a dearth of sunlight but they cannot tell us precisely how much we must have. Hence we do not know how long we must be in the sunlight, how great an area of our body surface must be exposed to it, nor how long we can go on without irradiation. But we do know that in the winter at least we do not receive as much as we need.

### SUNLIGHT CAN NOT BE STANDARDIZED

As the ultra-violet rays in sunlight vary, not only according to the season and the time of day, but also according to atmospheric conditions it is utterly impossible to determine with any degree of accuracy the dosage of sunlight needed in specific cases. Hence the heliotherapist has learned to proceed cautiously and experimentally. A sun bath of an hour may be safe enough on a certain day, but may, at the same hour, and in the same length of time, on the day following, cause a severe sunburn. One can not standardize sunlight with precision. In this respect, certainly, the ultra-violet lamp offers an advantage. For with the same apparatus, and with the distance from the lamp also the same, the time of irradiation practically determines the dosage. This dosage is now being worked out, although, of course, we must remember that some persons are much more susceptible than others to the radiation, just as individuals differ in their tolerance of our common drugs.

### IRRADIATED FOODS

The substance in the skin which responds to the ultra-violet is associated with cholesterol, and a similar substance is found in certain plants associated with phytosterol, which suggested that probably the vitamin could be produced in certain foods by irradiation, thus making unnecessary the ingestion of the unpalatable cod-liver oil. Irradiated grain foods, irradiated milk and similar products have given promise of usefulness. Such irradiated foods are now on the market, as are also concentrated products obtained by treating an impure ergosterol with ultra-violet rays. The dose of the latter product is extremely small, and an overdose is harmful. It is said to represent 100,000 times its weight of cod-liver oil as far as the antirachitic effect is concerned. Strange to say, however, when ergosterol, or a food containing it, is irradiated too long, the vitamin becomes inactive. Indeed, the whole study of irradiated foods, and of cod-liver oil substitutes generally, is still in its infancy, and much remains to be learned, if not in regard to the technique of their preparation, then certainly as regards proper dosage. A preparation of irradiated ergosterol has been approved by the council of pharmacy and chemistry of the American Medical Association, and may be accepted as quite reliable. But such products should be considered as medicine, to be taken under medical supervision.

### USE OF LAMPS

The same cautious course should be followed also in the employment of ultra-violet radiation when this is produced artificially. We know that sunlight does not ordinarily harm us if we avoid sunburn. But the radiation from arc lights or mercury vapor lamps embodies the wave lengths shorted than those found in sunlight which comes

to us filtered by the atmosphere. It is also more intense. For these reasons the radiation artificially produced is far more dangerous. But unquestionably, the contrivances to furnish ultra-violet and thus to compensate for our loss of normal sunshine, are, if used properly, of great value. It is not wise, however, to proceed to self-treatment without expert direction. Here also conservatism is the part of wisdom. Let those who have been specially trained, do the pioneering.

### THE ZONES OF ULTRA-VIOLET RAYS

The radiation from a mercury vapor lamp produces violet, blue, green, and yellow light waves, which can be filtered out; and also ultra-violet rays from the violet down to a wave length of about 1,850 to 1,870 Å. Waves shorter than 1,850 Å are cut out by quartz and are never found in the radiation from a mercury vapor lamp. The waves of the Dorno region, 2,900 to 3,130 Å, and the longer ones, have the action of sunlight, but are of course supplied in greater abundance. Like sunlight they stimulate metabolism, govern our calcium balance, increase the alkalinity and the iron content of the blood, sharpen the appetite, and may be used in the treatment of rickets, certain skin diseases, and of tuberculosis. Such skin irradiation produces a slight rise in the temperature, which soon falls to normal. It does not affect the blood pressure. If prolonged, it can, of course, cause sunburn, and it may cause inflammation of the eyes, this being due mainly to the waves shorter than about 3,050 Å.

Waves shorter than 3,000 Å are correspondingly more irritating and more dangerous to the eyes. Since these shorter waves are produced in the operation of electric welding, they are frequently encountered, and their dangerous nature should be kept in mind. Goggles of special glass designed to intercept them, are worn by the persons engaged in such operations; the spectators, however, are not so protected, and must look out for themselves.

### BACTERICIDAL RAYS

The waves shorter than 3,000 Å and longer than 2,000 Å are decidedly bactericidal, particularly those between 2,490 Å to 2,380 Å. But longer wave-lengths also have a killing effect on some germs, though in a much lesser degree. Indeed, this is true in a measure in regard to the violet, the blue, and the green of the visible spectrum. Speaking generally, the longer the wave lengths, above 3,000 Å, the less effective are the rays in the destruction of bacteria.

### CHEMICAL ACTION

Waves shorter than 3,000 Å also convert oxygen into ozone, hence this substance is always in evidence when an ultra-violet lamp is in operation. Ozone is a very active oxidizing agent, and in dilution acts on us as a stimulant. It is interesting in this connection to note

that the solar radiation forms ozone in the upper regions of the atmosphere, and that when the sky is clear, and when the wind is from the west or the southwest, some of the ozone is found at the earth's surface, thus augmenting the exhilarating effect of the outdoor air, when we are taking a stroll under such weather conditions. It may explain also why we are apt to feel less energetic when the wind is from the east, for then the ozone is absent. Old-fashioned fishermen may even contend that it provides justification for their deep convictions to the effect that "When the wind is from the east, the fishing is the least." But no one gives credence to what fishermen say.

### A NEW TOOL FOR THE CHEMIST

To the chemist the ultra-violet lamp has opened up new methods of identification. Since so many substances exhibit characteristic fluorescent properties, this fact may be utilized for identification and for the detection of small quantities of certain contaminations or adulterations. The ultra-violet lamp may be used in food analysis, in clinical chemistry, and in mineralogy to identify rock components. The modern Sherlock Holmes will use not only his microscope but also his ultra-violet lamp. In the examination of documents, to detect suspected alterations, to establish the authenticity—or the reverse—of old paintings, this strange radiation is of great assistance. In the paint industry it may be employed to study the resistance to sunlight of various paints and varnish mixtures. Its applications for the chemist seem indeed almost endless. It is a tool of great value to the analyst as well as to the physician. But it must, of course, be handled with caution. Such a lamp is not a plaything.

### ANCIENT AND MODERN SUN WORSHIP

Man has since time immemorial recognized sunlight as a natural agency of paramount influence. Many primitive races worship the sun as a deity, a practice at one time quite general and extending over long periods of time. Our American Indians still conduct their sun dances. The ancient sun worship, not only in Africa and in Asia, but also in Europe, and on this continent, had its gruesome aspects for it entailed, frequently, human sacrifice—sacrifice to the sun god. The modern sun cult, should, however, exhibit no such inhuman features. Only ignorance, leading to the reckless misuse of sun therapy, can call for victims. Let us hope, therefore, that this new health-giving agency may be employed wisely and conservatively by the enthusiastic devotees of the modern sun cult and that experimentation in this field may be limited to persons who have the necessary knowledge and skill.

# THE MOON AND RADIOACTIVITY [1]

By V. S. Forbes

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In a study of the surface features of our satellite one is immediately impressed by the remarkable sharpness and freshness which many of those features exhibit. Further, one is struck by the fact that evidences of compressive action are in the minority, whereas the moon's crust shows clearly innumerable clefts, rifts, and fractures pointing to an extensional tendency beneath its outer envelope. This is hardly in accordance with our ideas of the appearance of a sphere which has lost all its heat; everywhere it should show signs of intense contraction, and arcuate mountain ranges should be more frequent than upon the face of the earth.

It is now generally accepted that the moon must have cooled to something like its present condition long before the earth came to the state in which its igneously fluid mass was crusted over. According to Dr. R. H. Rastall [2] the moon is very probably the missing two-thirds of the earth's sialsphere, which in the liquid state was stripped off by some form of tidal resonance. A certain amount of sima was stripped off at the same time, giving the moon its density of 3.46. (Density of sial, about 2.7.) Support is lent to this view by the recent investigations made by Dr. F. E. Wright [3] on the optical course of the moon's radiation. He states that "results clearly indicate that at the surface of the moon, no dark rocks, low in silica, nor iron, nor obsidians are exposed in appreciable amounts; but light-colored rocks high in silica and powders of transparent substances are possible." In other words, the moon's surface is predominantly of sial.

Now it seems highly improbable that the many well-preserved surface features of the moon could have been formed at that remote period before the earth had obtained a solid crust. It is true that the

[1] Reprinted by permission, with author's alterations and additions from the Geological Magazine, vol. 66, No. 776, February, 1929.

[2] The Continents and the Origin of the Moon, Nature, May 2, 1925.

[3] Carnegie Institution of Washington, Year Book, No. 26, 1926–27, p. 383.

ordinary agents of erosion and degradation are absent on the moon, but there still remain two destructive forces to be reckoned with; forces which should surely have obliterated or dulled the trace of finer markings in the immense period of time at their disposal. The first of these is differential expansion and contraction in the rocks, aided by gravity, and rendered far more potent than on the earth by the tremendous temperature range and the abruptness of thermal changes experienced on the atmosphereless moon. This force should operate to cause exfoliation and crumbling of every exposed rock surface, causing a slow but inevitable degradation of relief. The rock screes would creep downwards through expansion and contraction. The absence of water and organic matter would prevent cementation of the talus, and movement would continue until a low angle was reached. It should be noted that the smaller gravity value on the moon is offset by the fact that this reduces friction, so the capacity of loose material for downward motion is not thereby affected.

The fact that this temperature change now occurs but once in every 14 days does not diminish the value of this argument. For if the moon's features were formed before the earth's crust had cooled, these features were then more often exposed to the temperature changes, owing to the moon's then greater rapidity of rotation and revolution. Subjection to this temperature range, even if only once every 14 days throughout the immense period which has elapsed since pre-Archeozoic times, must surely have operated to degrade all the moon's features in a marked degree.

If during a brief period the moon possessed an atmosphere, the ordinary agents of erosion and denudation were then present to destroy the relief rapidly. Formation of the major part of the original surface features necessarily preceded the loss of the atmosphere, since as long as volcanic action occurred, gases would be emitted to compensate wholly or partly for the diffusion of the atmosphere into space. It is indeed surprising that evidences of this period of active degradation as well as the subsequent and exceedingly long period of slow degradation, are so conspicuously absent in many of the moon's surface features. If, on the other hand, the original surface features were not of volcanic formation, as assumed above, an explanation must be sought for a phase of violent vulcanicity at a later stage in its history.

The second destructional force likely to obliterate the moon's sharp relief is the continuous bombardment of meteors and meteorites to which it is no doubt subjected. The moon being destitute of any protective gaseous envelope, all meteorites and meteors entering its gravitative field will come into contact with its surface. The impact

of these bodies will by their shock, and also by hitting screes directly, greatly accelerate the downward motion of rock particles.

Again, the moon exhibits on its surface a color-range between the dark lavas of the "seas" or maria and the dazzling white ray systems which surround the largest craters or vulcanoids. One can not believe that this gradation in coloring could have persisted since the moon's formation, under an incessant hail of meteors. For if a meteor's force of impact be sufficient, its constituents will be immediately volatilized by the resultant heat.[4] The meteoric material will thus be scattered, but will settle down upon the crust. In time the whole surface of the satellite will be covered by a homogeneous layer of meteoric dust which will give the lunar features a uniform hue. If on the other hand the meteoric mass merely pits the surface without being volatilized, the effect will be to change the color for the area of that pit. Continuous pitting of the surface will ultimately reduce the whole surface to the same hue.

Against this it may be said that a certain number of meteorites will fail to reach the face of the moon visible to us, owing to the earth's superior gravitative attraction, and that most meteorites will fall upon the hidden face. But again it must be remembered that the moon has not always rotated at its present speed, and that during the initial stages of its history it probably exposed every part of its surface equally to meteoric attack. If it ever possessed an atmospheric envelope, its loss must have been an early occurrence, and it can not have acted as a protective mantle for long. If, on the other hand, it be assumed that the loss of the atmosphere is of recent date, then it is the more difficult to explain the absence of marked degradation by weathering in many of the surface features.

It may be argued that it is possible that the earth and moon have but recently reached a part of space where meteors exist, and that therefore there has not yet been time for the falling bodies to produce any marked effect upon the moon's surface. However, even if one or other of these arguments be accepted to account for the still-existing diversity of color evident upon the moon, there still remain to be explained (a) why our satellite shows signs of expansion rather than of contraction, (b) why many of its features are so clear in spite of degradation due to differential contraction and expansion of its surface materials.

Question (b) induces the idea that those features of the moon which are clear and sharp are so because they have not long been exposed to the degradational forces; in other words that they are of comparatively recent origin. Both questions seem to be satisfactorily

[4] G. K. Gilbert. Bulletin Philosophical Society of Washington. XII, 1893. p. 259.

solved when one applies to the moon Joly's [5] well-known theories of radioactivity, which seek to account for geological periodicities upon the earth.

We have accepted the assumption that the moon was originally derived from the outer layers of the earth. Therefore it must have the same radioactive constituents as our globe. Furthermore, radioactivity should be greater in the moon than in the earth, since the former contains a larger proportion of sial, and the lighter acidic rocks are more radioactive than the denser basic rocks. Density considerations lead us to expect that whereas the inner core of the moon is sima, a large part of its volume down to a very considerable depth beneath its crust will be of sial. Joly has advanced the hypothesis that in the earth, heat accumulations due to radioactivity beneath the continental blocks will escape when the substratum is liquefied, and the heated areas are brought beneath the thin ocean beds, through the crust being rotated over the liquid substratum by tidal drag. He has also shown that under this theory a continuous belt of land around the equatorial regions of the globe would be an unstable arrangement, for then no amount of slipping of the crust over the molten interior would provide any means of escape for the heat. The continuous belt would ultimately be broken up by melting.

On the moon, however, not only is there a continuous belt of sial around the equatorial regions, but the whole surface of the sphere is underlain by a thick stratum of that material. Obviously heat accumulated within the moon due to radioactivity, can not escape by the means advocated for its dispersion in the earth. Only a period of cataclysmic vulcanicity marked by violent eruptions, rending of the crust and outpourings of lava can release the pent-up heat. It is to such revolutions that the surface phenomena of the moon may tentatively be ascribed, the state of excellent preservation of the younger features pointing to comparatively recent date for their formation.

An examination of the moon's features appears to lend very substantial support to this conception. Everywhere there are traces of exceptionally violent eruptions, craters occupying a very large proportion of the surface. That the largest craters as a general rule appear to have been formed first, confirms the expectation that the initial outburst of the compressed lavas would be of great violence. Concurrently the great rifts, clefts, and fractures were formed, as the thin skin of unmelted crust failed to extend to cover the now greater volume of the sphere. For, as heat accumulated within the crust, so would the constitutents of the interior tend to become liquefied and less dense. Only the intense pressure would keep them from liquefaction. However, a time would come when the crust was so far

[5] The Surface-History of the Earth, by John Joly, Oxford University Press, 1925.

weakened from beneath as to be no longer strong enough to resist the internal pressure. Once lava had pierced the crust, pressure within would be lowered and rapid liquefaction and expansion would ensue. This subcrustal liquefaction would be confined to a substratum relatively thin when compared with the moon's radius. The lower limits of this stratum would be determined by the interaction of heat and the pressure of the superincumbent magma and crust; the upper limits by the conductivity of the surface layers. The volume of the moon would be increased and lava would rise in the innumerable fractures caused in the crust. Where the fractures were relatively narrow, lateral conduction in the cool upper layers of the crust would congeal the lavas before they could issue upon the surface. Where the fissures were wider, as we must suppose them to have been beneath the maria, conduction was insufficient to solidify the lavas, which thus were able to be extruded upon the surface. Evidence of internal expansion is seen in the linear arrangement of many groups of small vulcanoids, which mark lines of fracture in the crust. A fine example of this is the line of craterlets over 200 miles long between the vulcanoids Catherina and Abulfeda.

Shaler[6] observes that "those (fissures) which are in appearance sufficiently conspicuous to be mapped lie mostly in the central part of the visible surface, between the parallels of 30° north and south of the moon's equator and within 30° east and 50° west of the central meridian. They are thus remarkably rare in high latitudes and apparently seldom near the east and west margins of the visible part of the sphere. This apparent feature of distribution may be due to the oblique view of these marginal fields." That this distribution is apparent rather than real as suggested by the previous sentence is unlikely, for surely if obliquity of view tends to render these features invisible, this effect should operate at equal distances from the central meridian, whereas this is not the case.

An explanation of this distribution of the most conspicuous fractures may lie in the effects of tidal forces. The moon exhibits a fossil tide which has been estimated to be too large for the orbit it now occupies, the result of recession from the earth of the moon, and the inability of the latter to adapt its form to its position with reference to the earth. Liquefaction of the substratum would offer an opportunity of rapid adjustment of the moon's figure. The rifting of the proximal surface indicates that there the strains of adjustment were greatest, and a like area of rifting probably exists on the distal portion of the moon. Apparently the crust tended to fracture more on the proximal and distal areas, where it became re-

[6] N. S. Shaler, A Comparison of the Features of the Earth and the Moon, Smithsonian Contributions to Knowledge. Vol. XXXIV, 1903. p. 45.

lieved of support by migration of subcrustal magmas in the direction of like latitudes on the limb, than the latter areas where it became subjected to a buoyant thrust. The present existence of an excessive fossil tide, indicates either that during the moon's last phase of volcanic activity its adjustment of form to its position was incomplete, or that the excess is a measure of the moon's recession from the earth since the last phase of vulcanism.

The maria occupy a third part of the moon's visible surface, and most observers are agreed that these are outpourings of lava, but a comparatively thin layer upon the surface. Craters are relatively rare in these areas, owing no doubt to the fact that all but the highest of them would be covered in the lava flows. That the formation of the maria occurred after most of the major craters appeared is inferred from the melting of crater walls by the maria, a phenomenon visible in numerous places. Failure of the maria to coincide in location with that area where fracture by tidal forces appears to have been most intense, seems to indicate that their positions were determined by another factor. Local fragmentation of the crust and consequent extrusion of the maria may have resulted from a high concentration of radioactive materials beneath those areas. Such areas would be characterized by higher temperatures than elsewhere. This would operate to thin the crust greatly, causing much fracturing, and would also render the magma more fluid than elsewhere, facilitating the flow of the extruded lavas.

The maria occupy the lower portions of the moon's surface. Barrell[7] supposes this depression to have been accomplished by the ejection upon the surface of magma from below the level of isostatic compensation. This loading of the crust with material heavier than any found above the level of isostatic compensation would cause a slight subsidence of the crust, which depression would be enormously increased by lateral compressive stresses. We have seen that the maria probably occupy the most fractured portions of the crust, and the addition of several thousand feet of lava, a relatively thin covering, does nothing to reinforce the strength of those shattered areas. As outlined in the following paragraph, lateral compressive stresses are likely to occur at the close of a revolution, shortly after the extrusion of the maria took place. These horizontal forces would naturally find easiest expression in the shattered parts of the crust covered by the maria. The maria are thus probably not in a state of isostatic equilibrium, since by far the greatest part of their subsidence must be ascribed to action of lateral compressive forces. The supposition is that they are of recent formation, geologically speaking, and are at present moving towards a condition of isostatic

[7] Annual Report Smithsonian Institution. 1928. pp. 295–296.

equilibrium. Suess [8] was one of the first to note the depressions in which the maria occur. He observes that "The regular peripheral surface fractures which surround the Mare Humorum at some distance from its margin, and other similar examples show, however, that in some cases the circular subsidence extends beyond the surface of the lava." The hypothesis herein adopted appears to be in good accord with this observation.

The moon having got rid of that fraction of its accumulated internal heat which brought about liquefaction of the substratum and consequent convection currents, its crust is now a little too big for its cooling and contracting interior. Some of its internal mass has also been lost by extrusions of lava upon the surface. The fissures originally formed in the extension of the crust can not now be closed again by the efforts of the outer envelope to contract with the shrinking substratum, for the fissures are filled with solidified lava. Accordingly the weakest parts of the surface are subjected to buckling and wrinkling as the more rigid parts of the crust are thrust against them. As outlined in the previous paragraph, the maria are particularly susceptible to further depression as the less fractured portions of the crust exert a lateral pressure upon them. Due to the same forces, the surfaces of the maria, while plastic are thrown into the numerous anticlinal folds which they exhibit. A particularly fine example of this folding is visible in the Mare Serenitatis, where a meridional anticlinal chain with syntaxis and linking of arcs stretches from border to border. A meridional line of five small vulcanoids on the face of the same mare points to a line of fracture in the crust beneath the lava, which latter, subsequent to its extrusion, was pierced by minor eruptions along the line of fracture.

The existence of mountain ranges in close association with the maria, points to the fact that these too were caused by pressure in the crust striving to accomodate itself to a contracting interior. Where the rigid crust thrust itself most intensely upon the less rigid maria, the edges of the latter were crumpled and thrown up into the ranges which in many places border the maria. That the mountain ranges were elevated after the craters is shown by the fact that the latter are occasionally seen to be distorted or deformed by the former features.

The terrace effect within many of the craters, due to stages in the sinking of the lava within them, may possibly be ascribed to lessening of internal pressure as an adjacent mare was poured out upon the moon's face. Then each terrace would mark a pause in the formation of a mare, and the drop in the lava would be produced by a reduction in pressure due to renewed extrusions beneath the mare.

[8] E. Suess, Das Antlitz der Erde. III. 2. chap. 26, p. 685.

As previously stated, there is strong evidence that the formation of the maria occurred at a late stage in the period of vulcanism. The earlier stages were characterized by the eruption of thousands of craters, and these must inevitably have discharged large volumes of gases. It is possible that these gases formed a temporary atmosphere which, even if very tenuous, operated to check the rapidity of loss of heat into space. Back radiation from gas molecules and fine particles of suspended volcanic dust would reduce the rate of heat loss. Carbon dioxide is a common product of volcanic activity, and by reason of its density it would be retained at the moon's surface for a longer period than lighter gases. It predominates particularly during the closing stages of vulcanism, and would thus accumulate in largest quantities about the time of the extrusion of the maria. Under cover of this protective mantle, the lavas which formed the maria would assume a wider lateral extent than would have been possible had they been extruded at the inception of vulcanism when there was no atmospheric envelope to check loss of heat. Indeed, the extrusion of the maria may only have become possible when an atmosphere was provided. If this gaseous envelope did exist, it would not have remained long after the close of vulcanism, but would have been dispersed into space, due to the moon's inability, owing to its small mass, to retain gases against their diffusive tendency for any extended period of time.

The fissures on the high ground are those formed at the inception of vulcanism. A different explanation must be offered for those fissures seen upon the maria, especially as Shaler [9] states that these phenomena were amongst the last of the moon's features to be formed. These fissures appear to be rift valleys, and their occurrence on the maria where obvious signs of compression are visible, is at first hard to explain. However, it is to be noted that the course of the fissures is at high angles to the prevailing direction of the ridges on the maria. In other words, the forces which raised the ridges would not tend to prevent the formation of the fissures, or to close them up if these latter were of earlier date than the ridges. The rift valleys on the maria can be ascribed to faulting above fissures in the surface upon which the maria were extruded. These fissures ran parallel to the line of the compressive forces which raised the ridges. In these deep-seated fissures the molten magma was sinking with the contracting substratum, and the surface of the maria becoming relieved of support in these linear areas, sank, forming the fault troughs now visible.

An alternative suggestion to that made previously regarding the origin of the ridges is that they were also formed above fissures in

[9] Op. cit.

the surface upon which the maria were extruded; but these fissures were at right angles to the compressive forces. These forces caused the magma in the deeply covered fissures to be squeezed upwards, ridging the surface of the maria. This will explain the absence of accompanying synclines, which one would expect to find if the ridges had been formed by a simple wrinkling of the maria due to lateral pressure.

Barrell [10] advances strong evidence in support of the assumption that the lunar craters were not formed all in one phase of vulcanicity. In the younger craters there is a sharpness of definition and a steepness of slope which is absent in the older craters. Craters of the former type are frequently superimposed upon the latter. The ancient craters give evidence of previous revolutions in the same way as do the stumps of denuded orogenic belts upon the earth.

The freshness of many of the features on the lunar surface and the persistence of color gradations, induces the conclusion that a revolution has occurred recently, geologically speaking. The moon is now in a quiescent condition accumulating heat in the substratum, and therefore does not radiate any perceptible heat. As time advances, the lunar features will inevitably lose their sharpness of detail and gradation of color, until a further period of vulcanism restores the surface to the condition which it now exhibits. During this future liquefaction of the substratum, the present excess material in the fossil tidal protuberances will tend to withdraw in the direction of low latitudes on the limb, with a renewed fracturing of the crust on the proximal and distal surfaces. Since the moon will by then have retreated further from the earth, its fossil protuberances will be more disproportionately large than they are now.

If we adopt the not entirely unreasonable assumption made earlier in this article, that the moon during part of its early history possessed an atmosphere similar to the present terrestrial atmosphere, then the fact that no traces whatsoever of water action have ever been recognized upon its surface requires explanation. If we assume the original surface features to have been of nonvolcanic formation, then the atmosphere may have become diffused into space before the effects of vulcanism were impressed upon the ancient surface. This vulcanism could be accounted competent to destroy any traces of water action which might previously have existed. The conception of a revolution has had to be introduced to validate the hypothesis.

If, on the other hand, we assume that the original features of the moon were volcanic in formation, then, as previously set forth,

[10] Op. cit., pp. 304–305.

it is probable that the atmosphere was maintained until at least the close of vulcanism. Then the traces of water action may either have been obliterated by the agents of degradation previously enumerated, or have been destroyed by a later phase of vulcanicity. The first explanation scarcely seems probable, since innumerable fine markings exist on the moon's surface which should have been obliterated if river courses had been hidden by the effects of degradation. The second explanation points to revolutions at a date subsequent to the loss of the moon's atmospheric envelope. The gaseous envelope temporarily provided by these phases of vulcanicity was apparently insufficient to impress upon the moon's surface the phenomena of water action.

Taylor's suggestion [11] that the moon was acquired by capture during the early stages of the Tertiary, offers another explanation of the freshness of many of the moon's features. Then this can be explained by supposing that the moon has but recently arrived from a part of space where meteors do not exist. Again, if the moon were in a part of space far removed from any star, its surface temperature would be in the region of the absolute zero; nor would any temperature changes due to an external source be experienced to degrade its features. Taylor seeks to explain the terrestrial Tertiary orogenesis by the capture of our satellite, but fails to advance a cause for the equally important periods of diastrophism of earlier geological ages. However, even if this theory be adopted, we have still to explain the lack of signs of marked contraction, and the evidence of extensional tendencies beneath the moon's surface.

According to Jeffreys,[12] orogenesis is probably due to horizontal crushing stress developed in the outer layer of the earth. This outer layer can undergo no further cooling and contraction, and is therefore too large to fit the contracting substrata, which lie between the crust and the region at the center of the earth where no appreciable change of temperature takes place, and therefore no change of volume.

We have seen that evidences of compression are visible upon the moon, but are not developed to that degree which would be expected if any consideration of its radioactive content were neglected, as has previously been the case. In this paper an attempt has been made to demonstrate that there are good foundations for believing that a far greater proportion of the moon's volume is composed of radioactive-rich materials than is the earth. The foregoing arguments induce the supposition that due to this high proportion of heat-generating

[11] Theory of Continental Drift. Tulsa, Okla. 1928. p. 175. (A symposium on Wegener's hypothesis.)

[12] "The Earth," by Harold Jeffreys. Cambridge University Press. 1929. p. 279.

elements, our satellite has attained only that early stage of cooling where the surface layers are too small to fit the interior, and therefore are faulted and rifted. Future evolution will move in the direction of cooling and contraction of the substrata, until the crust becomes too large to fit the interior. Horizontal crushing stresses will then be developed in the crust, causing diastrophism. Periodical revolutions resulting in a hydrostatic condition of the upper layers of the substrata, will temporarily afford a relatively rapid means of escape of heat by convection from the lower layers. Absence of marked contraction is thus ascribed to the present high internal temperatures of the moon, and the lack of well-developed orogenic belts of terrestrial type is tentatively accounted for under the main hypothesis adopted in this paper.

# MODERN CONCEPTS IN PHYSICS AND THEIR RELATION TO CHEMISTRY[1]

By Irving Langmuir

Only about 35 years ago, during the nineties of the last century, knowledge of the physical sciences had advanced to such a point that many of the foremost physicists and chemists began to believe that the rate of progress of fundamental knowledge must be slowing up. The concepts of length, mass, time, energy, temperature, electric, and gravitational fields, etc., had been given precise meanings and were regarded as having an absolute existence quite as certain as that of matter itself. The phenomena of nature were explainable in terms of natural laws expressing relations between these absolute quantities. It seemed that the most important of these laws of physics and chemistry had already been discovered and that the work that remained to do was largely a matter of filling in the details and applying these great principles for practical purposes.

The laws of mechanics had been verified experimentally with a high degree of precision so no one doubted that they were rigorous laws of nature. Back in about 1830, Hamilton had succeeded in generalizing these laws in a few simple equations which seemed to contain all the essential truths of mechanics. It was only necessary to know how the kinetic and potential energy of any given system varied with the momentum and the coordinates of its parts in order to have at least a formal solution of the way in which the system would behave at all times. Thus all future work in mechanics need only be considered an application of Hamilton's equations.

Complete knowledge of the nature of light presented more difficulties. Hamilton, about 1820, showed that all the known laws of geometrical optics could be explained quantitatively in terms of either a corpuscular theory of light or a wave theory. The experiments of Fresnel on the interference of light which were made about this time, seemed to disprove Newton's corpuscular theory, so that Hamilton's proof of the complete analogy between waves and corpuscles

[1] Presidential address before the seventy-eighth meeting of the American Chemical Society, Minneapolis, Minn., Sept. 11, 1929. Reprinted by permission from the General Electric Review, vol. 32, No. 12, December, 1929.

in the case of geometrical optics became only of academic interest. Through the study of the phenomena of interference, diffraction, polarization and absorption of light, the wave theory of light became firmly established. Light was supposed to consist of waves in some sort of an elastic medium which was called the ether.

About 1830, Faraday developed clear conceptions regarding the electric and magnetic fields and Maxwell, about 1860, by applying exact mathematical methods evolved the electro-magnetic theory of light according to which light waves consisted of fluctuating electric and magnetic fields which are propagated through space at a speed which could be calculated from electric and from magnetic measurements in a laboratory.

Although the acceptance of Maxwell's views came slowly one could not long remain skeptical after the production of electromagnetic waves of relatively great wave length by Hertz in 1884. It may also be said that Maxwell's theory was essentially an application of the mathematical methods which Hamilton had originated in his treatment of the laws of mechanics, to Faraday's concepts of electricity and magnetism.

Thus in 1895, the physicists seemed to have some justification for the attitude that the most important laws had been discovered. The laws of mechanics had not been improved upon in 65 years. Faraday and Maxwell had brought in precise conceptions of electric and magnetic phenomena and had shown that by classical methods like those which had been so successful in mechanics, all the laws of optics could be derived from those of electromagnetism.

In chemistry a somewhat similar state had been reached. After the evolution of the conception of the elements and of combining proportions based upon an atomic theory, rapid progress was made in accumulating data regarding the elements and their compounds. Faraday's laws of electrolysis and new methods for the accurate determination of atomic weights began to provide the chemist with quantitative laws almost as precise as those of the physicists. The work of J. Willard Gibbs had brought into chemistry rigorous laws as fundamental in their field of application as were those of Hamilton and Maxwell in physics.

These remarkable advances on the quantitative side seemed to overshadow in importance the more qualitative results that had previously been obtained through the stimulus of the atomic theory. Under the leadership of Ostwald, chemists began to adopt a much more critical attitude and began to distinguish carefully between what they considered experimental facts and hypotheses based upon these facts. Ostwald, although he recognized the convenience of the atomic theory, believed it must always remain impossible to

prove the existance of atoms or molecules. He therefore urged that chemists avoid as far as possible the use of such hypotheses. Perhaps the chief result of this attitude was to lead physical chemists to neglect those parts of chemistry where the atomic theory would have been most helpful and to devote themselves more specially to the fields in which energy relationships and thermodynamics were directly applicable.

Physicists in general did not doubt the existence of atoms and molecules, but had by means of this theory developed the kinetic theory of gases which had led to many new quantitative laws, verified by experiment. However, the physicists in general had little to do with atoms and molecules but were more concerned with the ether, in which they believed unreservedly, although direct knowledge of the ether was far harder to obtain than knowledge of atoms and molecules.

Perhaps one of the main reasons why the physicists were so sure of the ether and the chemists so doubtful of the atoms and molecules was an unconscious belief in the respectable old adage "Natura non facit saltum," Nature makes no jumps. Certainly in those fields of physics and chemistry in which rigorous quantitative laws had been found applicable no discontinuities or jumps such as those implied by the atomic theory had been found.

The discovery of X rays by Roentgen, in 1905, marked the beginning of an extraordinary revolution which is today still in progress. This sensational event revealed to the physicist that great and fundamental discoveries were still possible even in the field of radiation where physics had had such complete success. It immediately caused great numbers of physicists to study the phenomena of electric discharges and to look for other sources of radiation. The discovery of radium and radioactivity by Becquerel and the Curies soon showed the importance of these new forms of radiation to the chemist as well as to the physicist.

Although Stoney in 1874 had seen that Faraday's laws of electrolysis together with the atomic theory required that electricity should also have an atomic structure, and although in 1891 he proposed the name electron for these atoms of electricity, J. J. Thomson should be regarded as the discoverer of the electron. He was able to show that electrons were contained in all forms of matter and found that the electron must weigh only about $^1/_{1800}$ as much as a hydrogen atom.

The studies of radioactivity, largely by Rutherford and his students, showed that radium spontaneously disintegrated to form helium and proved to the chemist that atoms were not indestructible and even that transmutation of elements was possible.

By the application of thermodynamics to radiation processes Boltzmann proved that the total radiation, of all wave lengths, within a cavity in a heated body must increase in proportion to the fourth power of the absolute temperature; this law had already been found empirically by Stefan. By a further development of thermodynamic methods Wien, in 1896, derived an important law, known as Wien's law, by which the intensity of radiation of any particular wave length could be calculated in terms of the wave length and temperature. This law was found to agree with experiment in the case of visible radiation from incandescent solids, but serious discrepancies were observed when an attempt was made to calculate the intensity of infra-red radiation or heat waves. Lord Rayleigh and Jeans, in 1900, using what seemed to be unimpeachable methods based on the electromagnetic theory of light, arrived at an entirely different relation between the intensity of radiation and the temperature and wave length. This equation agreed excellently with experiments on the radiation of heat where Wien's law had failed but led to absurd results when applied to the shorter wave lengths of the visible spectrum. In fact, if the total radiation including all wave lengths were calculated from the Rayleigh-Jeans equations an infinite radiation density was obtained even at low temperatures. Thus by means of the classical theories of radiation it was found on the one hand by Boltzmann that the radiation increased with the fourth power of the temperature, and on the other by Rayleigh-Jeans, that the radiation was infinite at all temperatures.

It was shown in 1905, by Planck, that this paradox could only be solved by assuming an essential discontinuity in the energies or motions of electrons whose vibrations caused the radiation. This gave birth to the quantum theory, which within recent years has grown to be one of the most important theories of physics and chemistry. In 1906, Einstein showed that the photo-electric effect and many photochemical reactions could be explained in terms of the quantum theory if light itself consisted of discrete particles of energy or quanta, now usually called photons. Although such a corpuscular theory of light seemed utterly incompatible with the accepted wave theory, an increasing number of phenomena were discovered in which it seemed necessary to resort to this corpuscular theory. The really rapid development of the quantum theory, however, dates from 1913, when Bohr began to develop his theory of atomic structure by applying the quantum theory to Rutherford's more or less qualitative theory of the nuclear atom.

## RELATIVITY THEORY

Among all the changes in the ways of thinking which were being forced upon physicists at this time, the most important by far was

that which resulted from Einstein's relativity theory, first stated in 1905. In 1895, as we have seen, electromagnetic waves and matter were thought to be manifestations of the properties of an all pervading ether.

As an example of the way that the physicists thought of the ether I will quote from the preface to Lord Kelvin's Baltimore Lectures. This preface was written in 1904, but the lectures were those that were delivered at Johns Hopkins University in 1884.

> I chose as subject the "Wave theory of light" with the intention of accentuating its failures; rather than of setting forth the admirable success with which this beautiful theory had explained all that was known of light before the time of Fresnel and Thomas Young, and had produced floods of new knowledge splendidly enriching the whole domain of physical science. My audience was to consist of professorial fellow students in physical science. * * * I spoke with absolute freedom and had never the slightest fear of undermining their perfect faith in ether and its light-giving waves by anything I could tell them of the imperfection of our mathematics, of the insufficiency or faultiness of our views regarding the dynamical qualities of ether, and of the overwhelmingly great difficulty of finding a field of action for ether among the atoms of ponderable matter. We all felt the difficulties were to be faced and not to be evaded; were to be taken to heart with the hope of solving them if possible. * * * It is in some measure satisfactory to me and I hope it will be satisfactory to all my Baltimore coefficients still alive in our world of science, when this volume reaches their hands to find in it dynamical explanations of every one of the difficulties with which we were concerned from the first to the last of our 20 lectures of 1884. All of us will, I am sure, feel sympathetically interested in knowing that two of ourselves, Michelson and Morley, have by their great experimental work on the motion of ether relatively to the earth, raised the one and only serious objection against our dynamical explanations.

This Michelson and Morley experiment of 1887, through the theoretical investigations of Lorentz and others, kept growing in importance until it finally stimulated Einstein to evolve his relativity theory.

According to this theory space and time can not be considered as existing independently of each other. They can not in any sense be regarded as absolute but are both dependent upon the point of view of the observer. For example, Einstein showed that it has no meaning to say that two events which took place at a great distance apart occurred simultaneously. Some observers knowing of both events would have to say that event A occurred before B, while other observers moving at a different velocity from the first observers would conclude that B occurred before A.

It is not my plan to try to explain the relativity theory to you even if I knew how to do so, but it is rather to discuss the way in which this theory and others of a somewhat similar nature have gradually brought about profound changes in the viewpoint of the physicists

and how similar changes are beginning to occur in the attitude of the chemists. The importance of Einstein's work thus lies not so much in the facts or phenomena that can be explained by the relativity theory, but in the discovery of a new way of thinking as applied to physics. Somewhat similar methods of thought had, it is true, been used in some branches of mathematics and sometimes in philosophy, but Einstein subjected our elementary conceptions of space, time, mass, energy, etc., to a searching analysis quite new in the history of physics.

## CONCEPTS INVOLVE OPERATIONS

Prof. P. W. Bridgman, of Harvard University, has recently written a popular book entitled "The Logic of Modern Physics," in which he analyzes the changes in our concepts that have resulted primarily from Einstein's work. Bridgman's thesis is that physical concepts have meaning only in so far as they can be defined in terms of operations. He shows that this new attitude toward our fundamental conceptions is perhaps one of the greatest changes that has been brought about by Einstein's work. There is no question in my mind but that the recent remarkable advances in quantum mechanics that have been made by such men as Bohr, Heisenberg, Schroedinger and Dirac have been stimulated by the desire to formulate all concepts in terms of operations. Bridgman has not originated this method, but he, more than anyone else, perhaps, has been conscious of its widespread application in modern physics.

I should like to outline to you the way in which Bridgman develops this thesis and to consider how well it applies to the most recent changes that have taken place in physics and in chemistry. I believe the chemist can derive great benefit from the conscious application of a similar critical attitude in his own science.

Bridgman points out that "hitherto many of the concepts of physics have been defined in terms of their properties." An excellent example is Newton's concept of absolute time. The following quotation from Newton's Principia is illuminating.

> I do not define Time, Space, Place, or Motion, as being well known to all. Only I must observe that the vulgar conceive those quantities under no other notions but from the relation they bear to sensible objects. And thence arise certain prejudices, for the removing of which, it will be convenient to distinguish them into Absolute and Relative, True and Apparent, Mathematical and Common.
>
> (1) Absolute, True and Mathematical Time, of itself, and from its own nature flows equally without regard to anything external, and by another name is called Duration.

Thus, according to Newton, time and space have properties of a very abstract kind and are looked upon as "things" which exist inde-

pendently of all other things. There is, however, as Bridgman says "no assurance whatever that there exists in nature anything with properties like those assumed in the definition, and physics, when reduced to concepts of this character, becomes as purely an abstract science and as far removed from reality as the abstract geometry of the mathematicians." Nevertheless, these conceptions of space and time prevailed until the relativity theory was proposed.

In the development of this theory Einstein, in analyzing the concepts of space and time, considered what means are available by which an observer can measure distances between two points on a rapidly moving object. For example, imagine two planets moving past each other at high velocity and two observers, one on each planet, provided with means for observing each other and communicating with each other; such means, for example, as light signals. Einstein asks, what are the operations by which the two observers could compare their units of length and time? He finds that each observer would logically conclude that the other observer's unit of length is shorter than his own, and that the other's unit of time is longer than his own. Einstein thus proved that there can be no such thing as absolute length or time, or rather proved that the concept of absolute time has no meaning, for we have not been able to conceive of any method for determining the absolute time of any event.

In order to illustrate his thesis Bridgman considers in detail the concept of length. Probably one of the earliest concepts of length was obtained by counting the number of unit lengths that can be placed end to end between two given objects. For example, the number of paces are counted in walking from one object to another. An extension and refinement of this method is employed to-day when the standard meter at the Bureau of Standards is compared with a steel tape and this is then used to lay off a base line for a survey by triangulation.

As Bridgman suggests, it was one of the greatest discoveries of the human race to find that these operations performed with a measuring rod afford a useful and convenient means of describing natural phenomena.

During the transition from the earliest pacing of distances, to our modern refined measurements with the meter stick, the concept of length itself must have undergone radical modifications since the operations involved had been modified. For example, if distances are to be paced, it has no meaning to consider distances of $\frac{1}{1000}$ of a pace unless the concept is modified to include arbitrarily chosen methods by which a length equal to $\frac{1}{1000}$ of a pace may be determined. In our modern measurements with a steel tape we must

measure the temperature of the tape and the force used in holding the tape taut, and then by means of the coefficient of expansion and the coefficient of elasticity, apply corrections to the observed length. It is hard to see what methods primitive man could have used in applying such corrections to his distances measured by pacing.

Why do we now apply such corrections? Merely because it has been found by experiment that the result that we get by applying such corrections is a quantity which proves to be more useful in describing natural phenomena than the results we get without these corrections. We must not think that we do it in order to obtain the "true" or "absolute" length.

To-day we have many other methods of measuring length than by use of measuring rods or steel tape. For example, we use optical instruments and measure distances by triangulation, we measure heights in the atmosphere by means of a barometer, we measure the distances of spiral nebulae by measuring the brightness of the Cepheid variables observed in them by our most powerful telescopes, we measure the lengths of molecules by finding the area of a water surface over which a given amount of oil will spread, we calculate the diameters of molecules by measurements of the viscosity of gases by means of the kinetic theory, or we use X-ray diffraction patterns or, finally, we calculate the diameter of an electron from its mass and charge by means of the electromagnetic theory assuming that all the energy of an electron lies in the electric field outside of its surface.

Now each of these measurements of length involves an entirely different set of operations and, therefore, fundamentally, according to Bridgman, we should regard them as different concepts; logically, in fact, they should all have different names. It has, however, been found as a matter of experiment that two or more of these methods when applied to the measurement of the same distance give results which agree more or less with one another. This, then, is our justification for calling all these concepts by the same name, length.

We may, if we wish, extrapolate and predict that by applying suitable corrections to each of these methods of measuring lengths we may be able to get better and better agreement between them. Such methods of extrapolation may be useful and stimulating but we must always expect that sooner or later we will be unable to obtain agreement between these methods with more than a limited degree of accuracy. This may not be due merely to experimental difficulties but may often result from unavoidable fuzziness in the concept itself. Such concepts as the diameter of a complicated molecule, or the mean free path of a molecule in a gas are inherently fuzzy conceptions and can mean not much more than when we speak of

the diameter of a tree or of the length of the waves during a storm at sea.

Perhaps the strongest reason for the general belief in the existence of an absolute space lay in the apparently perfect agreement between our measurements of length and the theorems of Euclidian geometry. During the last century, however, mathematicians began more and more to realize that Euclidian geometry was only one out of many possible logical geometries, and since all of these were based solely on certain axioms or postulates none of them had any real or necessary connection with physics. The apparent agreement between our physical observations and Euclidian geometry, therefore, does not prove that space must have the properties postulated in Euclid's axioms.

## MODELS

As chemists we are all more or less familiar with various models of atoms and molecules that have been proposed within recent years. The structural formulas which the organic chemists have used for a good part of a century are another example of an extremely useful type of model. I want to discuss later some of the models which the physicists have used in giving more concrete forms to their theories. Logically, I believe, we should regard Euclidian geometry as a model devised primarily to help us "explain" natural phenomena.

Observation of nature reveals great complexity. We receive enormous numbers of impressions simultaneously and if we are to make progress in understanding phenomena we must concentrate on certain aspects of the things we see about us and thus discard the less important features. This involves a process of replacing the natural world by a set of abstractions which we have become very skilful in choosing in such a way as to aid us in classifying and understanding phenomena. Thus it was found useful to develop concepts or abstractions such as shape, position, distance, etc., and separate these characteristics of the phenomena from others such as color, hardness, etc Euclidian geometry was found useful in correlating these concepts of shape, position, etc.

Physicists and chemists have usually felt that they understood a phenomenon best when they could explain it in terms of a model or concrete picture. The chemist explained the law of multiple combining proportions in terms of atoms which combine together to form molecules. The heat conductivity, viscosity, etc., of gases was explained in terms of the kinetic theory, with molecules making elastic collisions with one another according to the law of probability.

When we use the atomic or molecular theories to explain phenomena in this way, we assign to the atoms and molecules only those properties which seem needed to accomplish the desired result; we

do not consider what the atom is made of nor what its structure is, but usually feel justified in assuming properties which are as simple as possible. For example, in the elementary kinetic theory it is assumed that the molecules are hard, elastic spheres, not because anyone really believes that molecules have these properties, but merely because these are the simplest properties we can think of which are consistent with the known facts.

What we really do, therefore, is to replace in our minds the actual gases which we observe and which have many properties which we do not fully understand by a simplified model, a human abstraction, which is so designed by us that it has some of the properties of the thing we wish to displace.

There is thus a difference of degree rather than of kind between the adoption of a mechanical model and the development of a mathematical theory such as Euclidian geometry. When the mathematical physicist develops an abstract theory of actual phenomena—for example, Hamilton's equations to summarize the laws of mechanics—he is in reality constructing a mathematical model. Mathematical equations have certain definite properties or rather they express certain relationships between the symbols which enter them. In a mathematical theory of physical phenomena the equations are so chosen that the relation between the symbols corresponds in some simple way to that which is observed between measurable physical quantities which are the bases of our concepts of physics.

Within recent years, especially in the development of the relativity and quantum theories, physicists have been making increasing use of mathematical forms of expression, and have been giving less attention to the development of mechanical models. The older generation of physicists and chemists and those among the younger men who are less skilled in the use of mathematics are inclined to believe that this is only a temporary stage and that ultimately we must be able to form a concrete picture or model of the atom, that is, to get a picture of what the atom is really like. It seems to be felt that a mechanical model whose functioning can be understood without the aid of mathematics, even if it only gives the qualitative representation of the phenomena in question, can represent the truth in some higher sense than a mathematical theory whose symbols perhaps can be understood only by a mathematician.

There is, I believe, no adequate justification for this attitude. Mechanical models are necessarily very much restricted in scope. The relationships of their parts are limited to those that are already known in mechanics (or in electricity or magnetism). Mathematical relationships are far more flexible; practically any conceivable quantitative or qualitative relationship can be expressed if desired in

mathematical form. We have no guarantee whatever that nature is so constructed that it can be adequately described in terms of mechanical or electrical models; it is much more probable that our most fundamental relationships can only be expressed mathematically, if at all.

In analyzing our attempts to describe nature, we have discussed concepts, models and mathematical theories. We find that they are all alike in that they represent human abstractions which are found convenient in describing nature. Going back a step further we must recognize that words themselves constitute elementary concepts. They are, it is true, much more vaguely defined than our concepts of physics and chemistry, but qualitatively they are very much like the latter; in fact, most of our misunderstandings in science arise from assigning reality to concepts whose main reason for existence is the fact that they are represented by a word. Logically we should aim to define our words in terms of operations. We should have in mind specifications by which we can test whether or not the word is properly applicable.

The progress of science depends largely upon (1) giving to words meanings as precise as possible; (2) definition of concepts in terms of operations; (3) development of models (mechanical or mathematical) which have properties analogous to those of phenomena which we have observed.

## MEANINGLESS QUESTIONS

A great deal of time and effort is wasted in scientific circles as well as in the world at large through failure to give sufficiently definite or useful definition of words and concepts. Bridgman emphasizes this in connection with his discussion of "meaningless questions."

In some cases questions fail to have meaning because of the more or less inherent fuzziness of the concepts involved. For example, if we compare two trees of about the same size it may have no meaning to ask which tree has the larger diameter, for no one has defined the diameter of a tree with the necessary precision.

A more important class of meaningless questions arises when there are no conceivable operations that could be performed to arrive at a decision. For example, what is the meaning of the question, "Would the United States have entered the World War if the Lusitania had not been sunk?" Such a question may be a good subject for a school debating society, but no one is apt to think that the question has thereby been answered.

A study of meaningless questions may serve a very useful purpose in science. A statement that a certain question has no meaning may

be equivalent to stating a fundamental law of nature; for example, to say that the question, "What is the true velocity of the north star through space?" has no meaning is a fairly good statement of at least a part of the relativity theory.

In some cases it may have no meaning to ask whether or not there is a magnetic field in a certain portion of space. For example, suppose an observer, stationary on the earth, studies an electron in motion. The motion of an electron constitutes an electric current and experimentally he will observe the characteristic magnetic field surrounding this electron corresponding to this current. If another observer moves along with the electron, it will appear to him to be at rest, and, of course, he can observe no magnetic field. Otherwise, the presence or absence of a magnetic field around an electron or group of electrons could be used to determine absolute motion through space, which would be contrary to the relativity theory. The relativity theory thus requires that a magnetic field can have no real existence in any absolute sense.

We have seen that there are fundamentally as many different concepts of length as there are different ways in which length may be measured; nevertheless, we find approximate agreement between different ways of measuring the diameter of molecules and therefore are justified in assigning some *reality* to the concept diameter of a molecule. When, however, we ask what is the diameter of an electron, we find that the question is practically without meaning. It is true that we can calculate a diameter by assuming that the electron behaves like a charged sphere and that the classical laws of electrodynamics can be applied in this case. However, since we have no independent way of measuring this diameter, the process is one which involves reasoning in a circle.

There are many meaningless questions which afflict the chemist. It clearly has no meaning to ask what is the molecular weight of sodium chloride in a crystal. It is very doubtful whether it has any meaning to ask what is the molecular weight of water in liquid water. There are many cases where the concept of temperature has no definite meaning. Strictly speaking, temperature acquires meaning in terms of operations only in so far as an approach is made to equilibrium conditions. When the motions of molecules or atoms follow Maxwell's distribution law, that is, a random or probability distribution of velocity among the molecules, the concept of temperature becomes very definite. If, however, we deal with mercury vapor streaming into a high vacuum, or the conditions near a hot tungsten filament in a gas of low pressure, temperature has very little meaning. The same is true of the conditions frequently existing in an electric discharge tube such as a mercury arc, where the

electrons act as though they had a temperature of perhaps 50,000°, whereas the atoms have motions corresponding to far lower temperatures. Strictly speaking, neither the electrons nor atoms have well-defined temperatures, for the conditions are far removed from equilibrium.

In much of the recent discussion of the radiation hypothesis of chemical reactions, chemists have been discussing meaningless questions usually without realizing it. At first it was proposed that the radiation is absorbed by the reacting gas to form excited molecules in accordance with Einstein's photochemical law. When this is found not to be in accord with experiment, the concept of radiation is altered repeatedly as new experimental facts are found so as to make the modified theory continue to fit the facts. After this process has been carried on sufficiently, it no longer has any meaning to ask whether the reaction is caused by radiation or whether the radiation hypothesis is true.

In the studies of the properties of liquids, questions of the degree of ionization and of association and in some cases of internal pressures have been discussions of questions without meaning. A great deal of such discussion might be simplified or even avoided entirely if chemists would agree in defining these concepts in terms of operations.

Theories of valence within recent years have been afflicted with the same difficulties. As long as chemists deal with the ordinary valence rules of organic chemistry, they are dealing with concepts of valence which are actually defined in terms of operations; that is, the organic chemists know how to conduct experiments to prove that the valence of nitrogen in dimethylaniline is 3. The types of operations needed to establish the valence of magnesium in magnesium chloride are in many ways quite different, and they are still different if we consider the case of so-called quinquevalent nitrogen in ammonium chloride or heptavalent chlorine in perchloric acid. I believe that the chemist has much to learn from the physicist in regard to the proper method of attacking such problems as these.

The electrochemist has been troubled in locating the source of electromotive force in cells. The physicist has similar difficulty in finding the origin of the contact potential between metals. Fundamentally it must be recognized that unless or until there are methods by which these quantities can be measured, questions involving them have no meaning.

A practical example of the meaninglessness of some questions involving electric potential has recently arisen in the numerous proposals that have been made to construct a speed indicator for airplanes which will give the speed with respect to the earth's surface

independently of that of the wind surrounding the plane. It is reasoned that since the plane is moving through the earth's magnetic field a potential will be set up between the ends of a wire stretched between the wing's tips. It is only necessary to measure this potential difference in order to calculate the speed of the plane with respect to the earth. Careful analysis shows that the concept of the potential difference under these conditions is meaningless except with reference to a particular reference system. If this system is referred to the plane itself, this potential difference is zero quite regardless of what the speed of the plane may be with reference to the earth. A contrary result would conflict with the relativity theory.

Meaningless questions will assume far greater importance in future years. We shall see that the latest forms of the quantum theory now give us the best of reasons for believing that the identity of separate electrons within atoms or molecules may be partly or wholly lost, so that it may have no meaning to ask whether a particular electron we find as a result of experiment is the same electron which has previously produced an observed phenomenon. Even more far-reaching in its consequences is the Bohr-Heisenberg uncertainty principle according to which it has no meaning to ask what is the precise position and velocity of an electron or atom. An electron may have a definite position or a definite velocity but it can not in any exact sense have both. This doesn't mean merely that there are experimental difficulties in measuring them, it means that the concepts themselves (position and velocity) are relative to one another in a sense somewhat analogous to that of time and space in the relativity theory.

One's instinctive reaction when first questioned as to the objective reality of space, time, position, velocity, etc., is to object to such consideration on the grounds that they are too metaphysical. The recent advances in physics demonstrate that these methods of thinking are eminently practical; they represent, in fact, an attempt to get away from the metaphysical character of much of our thinking in the past. Instead of taking for granted objective realities corresponding to our concepts, we now deal with things which can be measured in the laboratory, the concrete data that we have to start from.

It is, however, very useful to retain the concept of reality. Bridgman suggests that reality should be measured by the number and the accuracy of the independent ways in which we arrive at similar measures of the concept in question. For example, owing to the fact that we have so many concordant methods of measuring the distance between the ends of a base line used for triangulation, we attribute great reality to the concept of length or, rather, to those concepts of length which are applicable in cases of this kind. We

thus have some justification in saying that two points are really one kilometer apart. We do not attribute, however, much reality to the concept of the diameter of an electron.

Thirty years ago the physical chemist doubted the existence of atoms or believed the concept was useless if not pernicious. A few years later the leader of this movement, Ostwald, in the preface of one of his books stated that he believed that the existence of atoms had been proved experimentally beyond question, although in previous books he had stated that there are always an infinite number of hypotheses that could be advanced to explain any given set of experimental facts.

To-day, what can we say in answer to the question "Does matter really consist of atoms?" Must we say that this is one of those meaningless questions?

Of course, the amount of meaning that can be attached to any such question depends upon the definitions of the words and concepts which it contains. If we mean by atoms indivisible and indestructible infinitely hard, elastic spheres, we are compelled to answer the question in the negative. In accordance with modern usage, however, we do not attribute any such properties to the atom. If, by the use of the word atom, we mean to imply principally the concept that matter consists of discrete particles which can be counted by the various methods which are now known for this purpose, we have the very best of reasons for answering the question in the affirmative. If in our studies of nature we discover evidences of discontinuities or of the presence of discrete natural units which can be correlated in a definite way with the numerical integers, we have come, it would seem, about as close to something absolute in nature as we can hope to get. Einstein in the relativity theory has taught us to look upon the intersections of world lines as the data upon which our observations of nature rest. Such points of intersections, which can be called events, are essentially discontinuities. In general they are all unlike one another. When we find in nature discrete units which in many respects appear to be identical with one another, and we can count these units, it would seem that the number of these units which obtain as a result is apt to be independent of our system of reference; therefore, they have in general, a certain kind of absolute significance.

In this respect, therefore, it seems that the atomic theory and the quantum theory in which integers play such a fundamental rôle may be considered as representing reality to a higher degree than almost any other of our physical and chemical theories.

Skepticism in regard to an absolute meaning of words, concepts, models or mathematical theories should not prevent us from using

all these abstractions in describing natural phenomena. The progress of physical chemistry was probably set back many years by the failure of the chemists to take full advantage of the atomic theory in describing the phenomena that they observed. The rejection of the atomic theory for this purpose was, I believe, based primarily upon a mistaken attempt to describe nature in some absolute manner. That is, it was thought that such concepts as energy, entropy, temperature, chemical potential, etc., represented something far more nearly absolute in character than the concept of atoms and molecules, so that nature should preferably be described in terms of the former rather than the latter. We must now recognize, however, that all of these concepts are human inventions and have no absolute independent existence in nature. Our choice, therefore, can not lie between fact and hypothesis, but only between two concepts (or between two models) which enable us to give a better or worse description of natural phenomena. By better or worse we mean, approximately, simpler or more complicated, more or less convenient, more or less general. If we compare Ostwald's attempts to teach chemistry without the use of the atomic theory with a good modern course based upon the atomic theory, we get an understanding of what should be meant by better or worse.

The more recent advances in atomic theory which have resulted from the development of the quantum theory and which have given us our present knowledge of atomic structure, afford us interesting applications of the new methods of thought, first introduced into physics and chemistry by the relativity theory.

The older atomic and molecular theories of the chemists took on more definite form through the development of the kinetic theory of gases, and through the electron theory and the study of radioactivity developed to a point where the atom is conceived of as consisting of a definite number of electrons revolving around the nucleus. The atom ceased to be indestructible and was no longer the smallest particle of matter which could take part in a chemical reaction. The nucleus, rather than the atom, became characteristic of the chemical elements. The chemical properties of the atom, however, depended upon the number and arrangement of electrons.

Bohr, in 1913, developed a marvelous new theory of the atom by combining Planck's quantum theory with a relative theory of the nuclear atom. He evolved several new quantitative mathematical relationships with new concepts such as energy levels, quantum states, etc., and showed how the spectra of elements could be explained in terms of these new concepts. He also gave a mechanical model consisting of electrons revolving in orbits about the nucleus according to laws which were partly classical and partly inconsistent with

classical laws. This model enabled him to derive certain mathematical equations from which he was able to calculate the frequencies corresponding to the different lines in the spectra of hydrogen and other elements, these frequencies being obtained from fundamental quantities such as the charge and mass of the electron and the quantum constant $h$, and did not involve any quantities dependent on the properties of the elements in question. The agreement between the theory and experiment was practically perfect, often enabling the frequency to be calculated with an accuracy of one part in 200,000.

Such remarkable success made most physicists and chemists believe that Bohr's model, for the hydrogen atom at least, was substantially correct. That is, they believed that Bohr's work proved that in a normal hydrogen atom the electron really described a circular orbit around a nucleus having a diameter and a frequency given by Bohr's model. Bohr himself never attached any such importance to the mechanical model, realizing that the important steps that he had taken consisted mainly in the introduction of new concepts and more particularly in the mathematical equations by which the observed frequencies in the spectral lines could be calculated.

Within recent years, largely through the work of Bohr himself and his students, and Sommerfeld, Schroedinger, and others, this theory of the hydrogen atom has undergone changes. According to Bohr's original model the radiation of energy corresponding to a spectral line resulted from transition in which the electron passed from one stationary orbit to another. No physical picture of this transition seemed possible. To account for the known phenomena it seemed necessary that the transition should occur so rapidly that the electron would have to move from one orbit to another with a velocity greater than that of light, and yet the train of waves in the resulting radiation lasted for relatively long periods of time, about $10^{-8}$ seconds. Radiant energy could be absorbed by the atom only if the frequency was just that which was capable of transferring an electron from one orbit to another definite orbit. Thus only one frequency could be absorbed at a time by an atom. It was found, however, that the frequencies corresponding to many lines could be scattered by a single atom. This seemed to require the presence within any given atom of a number of oscillators as great as the number of lines in the spectrum. One of the greatest arguments in favor of the original Bohr theory was that it avoided just this sort of complication in the atom.

To get rid of difficulties such as these, Heisenberg and Bohr realized that it was necessary to sweep out of the theories of atomic structure the many concepts which were characteristic of the me-

chanical models that had been proposed and to develop a mathematical theory of the atom which would involve only concepts that were definable in terms of operations. That is, the theory was one that dealt more directly with measurable quantities such as the frequencies of spectral lines. New methods of matrix calculus had to be evolved, a kind of calculus of discontinuities or discrete quantities instead of the calculus of continuous quantities which had characterized classical mechanics.

Only a little later Schroedinger, by developing De Broglie's wave theory of quantum phenomena, was able to build up a theory that we will now refer to as the wave mechanics, according to which the whole atom with all its electrons can be looked upon as a wave phenomenon. The electrons are no longer considered to be moving in orbits. For example, the hydrogen atom is found to have spherical symmetry instead of the axial symmetry of the old Bohr model of the atom. Yet this theory leads to identically the same equations for the frequencies of the lines in the hydrogen spectrum. We must not say that Bohr's theory of the hydrogen atom has been overthrown. Bohr's *mechanical* model has been superseded, but the more important model which is represented by the equations and the concepts which he evolved is even better to-day than it was when it was first proposed.

The wave mechanics which involves the calculus of continuous variables is not now in conflict with the Bohr matrix calculus of discrete quantities. The two theories are essentially merely different mathematical methods applied to a single fundamental problem. The resulting mathematical equations always agree with one another. One begins to believe that the mathematical theory is a far better model of the atom than any of the mechanical models which are possible.

The long-standing conflict between the wave theory of light and the corpuscular quantum theory now disappears with the new wave mechanics, the two aspects of light being somewhat analogous to the two aspects of the quantum theory, the wave mechanics and the matrix mechanics. In fact, the quantum theory now indicates that the electron itself can be regarded as a particle, or as a wave, just as light can be thought of as a photon or a wave. Whatever remained of the conflict between the wave and corpuscular theory of light and of the electron seems now to be fundamentally removed by the Bohr-Heisenberg uncertainty principle. To ask whether an electron is a particle or a wave is a meaningless question; the same is true of the question whether light consists of corpuscles or waves. One must answer that both of these are particles or waves according to the kind of operations that we may perform in observing

them. If we make an experiment which proves that an electron has a very definite position, then it would seem to prove that it is a particle. In that case, however, according to the uncertainty principle, we are not able to determine accurately the velocity and therefore can not predict where the particle will go.

Bohr has emphasized that the essential reason that the classical theory falls down in any detailed description of atomic phenomena is that our knowledge of such atomic systems can only be obtained through an act of observation which makes the observer inherently a part of the system. On the classical theory we assume that we could have knowledge of a completely closed system as though it were possible to know anything of what would go on in a strictly closed system. In order to make an observation some signal must be transmitted from the system to ourselves, and if we take this interaction completely into account we are forced to the quantum theory with its uncertainty principle.

An interesting feature of this new quantum mechanics is that the original conception of the relation between cause and effect which was universally accepted in science has lost its meaning. Atomic processes seem to be governed fundamentally by the law of probability. It has no meaning to ask when a particular radium atom will disintegrate, for no operation is conceivable by which such an event could be predicted. The same is true of every individual quantum process. We have no guarantee whatever that the expulsion of an $\alpha$-particle from an atom of radium has any immediate cause. In chemistry the formation of nuclei in supercooled liquids, etc., must be essentially quantum phenomena in which no cause can be assigned for the formation of the individual nucleus. By varying the conditions we may alter the probability that a nucleus will appear at a given point, but in no absolute sense can we ever make a nucleus form through a direct cause.

By a deeper analysis of this question of causality Bohr concludes that we have an option of two alternative descriptions of natural phenomena. If we choose to describe phenomena in terms of ordinary space and time then we must abandon causality. We may, however, retain the conception of causality if we are willing to describe atomic phenomena in terms of what the mathematician calls configuration space. Consider, for example, a helium atom with its two electrons. If we attempt to give the position of both of these electrons in space we would need a set of 3 coordinates, x, y, z, for each of the electrons, that is, 6 coordinates in all, 3 of which belong to one and 3 to the other electron. The mathematician, however, finds that the 2 electrons in general could also be described by 1 point in 6-dimensional space, for such a point has 6 coordinates.

This is a representation of 2 electrons as a single point in a configuration space of 6 dimensions. Now it turns out from Schroedinger's theory that the motion of electrons, or rather of the waves corresponding to them, can be completely described in the case of the helium atom by a quantity which has a particular value at each point in this 6-dimensional space or configuration space. The helium atom, however, can be described in terms of the motion of 2 electrons in 3-dimensional space if we are content merely to know the probabilities that the electrons may be found at any point in this space.

These matters undoubtedly seem very abstract to those of you who have not previously become familiar with them. I give them here mainly in order to illustrate how far the modern concepts of physics differ from those of 20 years ago.

If we must thus abandon our ordinary ideas of cause and effect, it may be asked why have the physicist and chemist so long believed that the whole teaching of science gave proof that every phenomenon resulted inevitably from the causes that led to it. I think the answer is that in the past scientists chose as the subjects for their investigations almost wholly those phenomena in which such definite relations as cause and effect could be found. These phenomena are those in which such enormous numbers of individual quantum phenomena are grouped together that the result is determined only by their averages. For example, when we study the variation of the pressure with the volume of a gas, the forces that we measure result from the impacts of great numbers of molecules, the average force remaining steady and definite. If, however, we only had one molecule in a small volume, the pressure exerted on the walls would be zero except for those instants at which the molecules struck the wall. It would then be impossible to predict in advance what the pressure would be at a particular time.

I think in trying to estimate the reliability of any of our scientific knowledge we should keep in mind that the whole complexion of a science may be made to change by the psychology of the investigators which governs the choice of the subjects that are investigated.

Our best knowledge of time and its relation to other concepts is that which we have obtained through Einstein. Yet in the whole relativity theory there is nothing to distinguish between positive and negative time, that is, between future and past, any more than there is between different directions in space, such as right and left. There thus appears to be something curiously incomplete in our knowledge of time, for every one of us knows the vast practical difference between past and future. Eddington, in his recent book, the Nature of the Physical World, discusses the "arrow of time" at some length.

He suggests that the second law of thermodynamics is the only fundamental law of nature which provides us with any distinction between future and past. One way of stating this law is that all spontaneous processes that occur in nature involve an increase in entropy. Eddington thus proposes that the positive direction of time can be defined as that direction in which the entropy increases. If we had a system in absolute equilibrium the entropy would be constant, and there would then be no arrow of time. This is in accord with the fact that in such a system there are no changes with time.

It is improbable that there are two independent fundamental factors which provide an arrow for time, so that it would seem that Eddington in having found one such factor has found the only one. There are, however, grave difficulties with this view. An arrow is a vector quantity which should have magnitude as well as direction. Now the rate of change of entropy does not seem to give us any measure of time. For this purpose we use phenomena which are as nearly reversible as possible, such as the swinging of a pendulum in a vacuum.

Fundamentally entropy is a measure of randomness. A random distribution of molecules in space and velocity is a system having the maximum entropy. If we throw a pack of cards out of the window and collect them from the ground they have become effectively shuffled. We would not expect by this process, starting with a shuffled pack of cards, to find them at the end in the order in which they come from the manufacturer. The direction in which the randomness increases thus provides an arrow for time. This arrow is, however, equivalent to that involving the increase of entropy.

It is still an open question, however, whether processes directed by intelligent beings may not involve a decrease in entropy. In fact it seems conceivable that the evolution of organic life on the earth is in some measure fundamentally contrary to the second law of thermodynamics. The inherent tendency of evolution seems to be to bring about an ordered rather than a random arrangement of parts, and in the future perhaps forms of life may evolve which cause a decrease of entropy on a large scale. Are we then to have some parts of the universe in which the arrow of time points in the opposite direction from that in neighboring parts?

Such speculations may seem fantastic. It is, however, I believe, of the utmost importance for the chemists and the physicists to evolve fundamentally sound conceptions of such things as time and entropy.

The profound changes in physical thought, particularly those represented by the quantum theory, are rapidly bringing about a revolution in physical chemistry. The third law of thermodynamics involving chemical constants has changed radically our methods of

studying chemical equilibria. The application of the quantum theory to band spectra promises to be of the utmost importance in chemistry. By enabling us to determine the moments of inertia of chemical molecules, the actual distances between the nuclei of the atoms in molecules can be found. Apparently our most accurate determinations of the heats of dissociation of elementary gases can be obtained from the band spectra through a knowledge of the energy levels of the various possible states of the molecules. In recent numbers of the Journal of the American Chemical Society, particularly in the paper of Giauque and Johnston, we see the beginnings of what promises to be the most accurate and fertile source of knowledge of chemical equilibria. From a detailed knowledge of the spectrum, for example, of oxygen, and without recourse to any other experimental determinations, the specific heat at all temperatures can be calculated, and the entropy of oxygen at all temperatures is thus found. This, together with the heats of reactions, which may be found by a similar method, makes possible the calculation of the degree of dissociation of oxygen and will ultimately make possible the calculation of all chemical equilibria.

The remarkable work of Dennison, Bonhoeffer, and Eucken in predicting and isolating parahydrogen should prove to the chemist how many of his chemical discoveries will be obtained in the future by the application of these new theories of physics.

Gurney and Condon have recently derived from the wave mechanics an explanation of the fundamental law of radioactivity. Similar methods will probably before long enable us to understand the processes involved in chemical reactions far better than we ever have before.

Physics and chemistry are being inevitably drawn closer together. It seems that there has never been a time when we can predict with such certainty rapid progress in fundamental chemistry, for the new theories of physics have as yet scarcely begun to be applied in the field of chemistry. The physicist on the other hand has much to learn from an increased knowledge of chemical phenomena which should provide him with a richness of experimental data far greater than any he has yet had an opportunity to use.

Unfortunately, although theoretical physics and chemistry are thus supplementing each other and in many respects are being merged into a new science, there are remarkably few men as yet that have received adequate training in both sciences. Before long, I hope, sharp distinctions between physics and chemistry will no longer exist, but at present there seems to be a very practical distinction.

In order to find approximately how many chemists are also active as physicists and vice versa, I have selected at random 100 pages of the fourth edition of American Men of Science (1927) which contains the names of 13,500 American scientists. Of these, approximately 2,700 are classed as chemists and 760 as physicists. Of the chemists 87 per cent are members of the American Chemical Society, while only 2.5 per cent belong also to the American Physical Society. Seventy-seven per cent of the physicists are members of the American Physical Society, while 3.3 per cent are also members of the American Chemical Society. Thus only about 3 per cent of the physicists and chemists of the United States, whose names are given in the American Men of Science, belong to both of the national societies. This leaves far too small a number of men who are capable or are properly prepared to carry on the important work of bringing these two sciences close together.

To pave the way for the coming revolutionary changes in chemistry we must be prepared to modify our methods of thinking, probably along lines now so prevalent in physics. But above all we must urge young chemists in the universities and after graduation to become thoroughly well trained in mathematics and in modern physics.

# WAVES AND CORPUSCLES IN MODERN PHYSICS [1]

By Louis de Broglie

[With 2 plates]

A study of the properties of common bodies leads us to put them into two classes: Composite bodies, which may be changed into more simple ones by appropriate operations, and simple bodies, or elements, which resist all attempts at reduction into simpler ones. An examination of the quantitative laws, following which these simple bodies, or elements, unite to make the composite ones, has led chemists for a century to adopt the following theory: a simple body is formed of small particles, each the same and called the atoms of this simple body; composite bodies are formed of molecules made by the union of several of these atoms. According to this hypothesis, the dissociation of a compound body into the elements of which it is composed means the breaking up of its molecules and the setting free of the atoms which the latter contain. The number of these simple bodies or elements actually known is 89. It is believed that in all there will finally be found 92. Therefore out of 92 different species of atoms all material bodies are constructed.

The atomic theory has been successful not only in chemistry but also in physics. If the substances of bodies are made of molecules and atoms, then their physical properties should be interpretable from their atomic constitution. The properties of a gas, for example, should be capable of explanation, supposing it to be formed of a very great number of atoms or of molecules in rapid movements. The pressure of a gas upon the walls of its container will be due to the blows of the molecules upon these walls; the temperature of the gas should be related to the mean agitation of these molecules, this agitation increasing as the temperature rises. This conception of a gas has been developed as the "Kinetic theory of gases" and has led to an explanation of the gas laws revealed by experiment. If the atomic theory is a proper representation of nature, the proper-

[1] Lecture delivered by M. de Broglie, who had been awarded the Nobel prize, at a conference at the Bureau of Arts and Measures, presided over by M. Painlevé, Jan. 26, 1930. Translated by permission from Revue générale des Sciences, vol. 41, No. 4, Feb. 28, 1930.

ties of solid and liquid bodies should be amenable to interpretation by picturing the molecules and atoms in such states as existing much closer to each other than in the gaseous state. The considerable forces which should then be expected to exist between the atoms and molecules should lead to an accounting for the properties of incompressibility, cohesion, etc., which characterize solids and liquids.

The atomic theory of matter has been confirmed by remarkable experiments such as those of M. Jean Perrin which permitted him to measure the number and weight of the divers atoms within a cubic centimeter. I will indicate here merely that the weight of an atom is extraordinarily small, yet the number per cubic centimeter is always enormous under ordinary conditions.

Without going further into the development of the atomic theory, we will merely add that in physics as in chemistry, the hypothesis, according to which all bodies are composed of molecules which themselves are built up of divers combinations of elementary atoms, has proved itself very fruitful and should be considered a good model of reality.

The physicists, however, were not content to stop here. They wished to proceed further—to know the structure of the atoms—in what way the various elements themselves differed from each other. In this task they were aided by the progress which had come in their knowledge of electrical phenomena. From the very beginning of the researches into the study of electrical processes it had seemed useful to treat electricity as a fluid—to suppose, for example, that the electric current passing through a wire was the flowing of some fluid through it. But as you know, there are apparently two kinds of electricity, positive and negative. Consequently it was natural to postulate the existence of two fluids, a positive fluid and a negative fluid. We may picture these fluids in two different ways: It is possible to suppose the fluid to be a continuous substance occupying uniformly the region it occupies; or better, to suppose it to be formed of clouds of small corpuscles, each corpuscle being a small ball of electricity. Experimental evidence has decided in favor of the latter. For some 30 years we have known that negative electricity is composed of small corpuscles, all identical and of extraordinarily small masses and electrical charges. These corpuscles of negative electricity have been designated electrons. It has become possible to eject these electrons out from matter and then study their behavior as free electrons in a vacuum. It has been shown thus that their motions are such as would be predicted by the laws of classical mechanics for small electrified particles. The study of the behavior of these small particles in electric and magnetic fields has led to the measurement of their size and electrical charge. These are extremely

small. The experimental knowledge of the corpuscular structure of positive electricity is less direct; nevertheless, physicists have reached the conviction that positive electricity is also subdivided into corpuscles, all the same in kind, and now called "protons." The proton has a mass, which, although very small, is nearly two thousand times greater than that of the electron. Its charge is equal to that of the electron but of contrary sign, positive instead of negative.

Electrons and protons have extraordinarily small masses; nevertheless this mass is not zero and an enormous number of protons make a total mass of considerable amount. It is therefore tempting to suppose that all material bodies, essentially characterized by weight and inertia, in other words, by mass, are built of an enormous number of protons and electrons. Looking at the matter in this way, the atoms of which the elements are composed and which are the materials from which all bodies are constructed, must be formed of protons and electrons. The 92 different atoms constituting the elements must be 92 different assemblages of protons and electrons.

The idea that atoms are formed from electrons and protons has been elaborated through the experimental work of the great English physicist, Sir Ernest Rutherford, and the theoretical studies of the Danish scientist, Niels Bohr. The atom of a simple body is supposed to be composed of a central nucleus carrying a positive charge equal to a whole number N times the charge of a proton and N electrons circulating about this nucleus. The assemblage is therefore electrically neutral. Without doubt the nucleus itself is formed of protons and electrons, the number of protons exceeding by N units the number of electrons. Almost all the mass of the atom is seated in the nucleus since this contains the protons. The protons are far more heavy than the electrons. The simplest atom is that of hydrogen. It is made up of a nucleus containing a single proton with one electron revolving about it.

What distinguishes the atom of one element from that of another is the number N of elementary positive charges carried within the nucleus. We can accordingly arrange these elementary bodies in a series formed of increasing values of N from hydrogen ($N = 1$) to uranium ($N = 92$). We may note that the order in which these bodies fall in such an arrangement is precisely that which would result from their atomic weights and chemical properties and which is known as the Mendeleeff classification.

I can not explain here in detail the idea that the atom is a kind of solar system formed of protons and electrons as has been advocated by the physicists. I will limit myself merely to saying that it allows the interpretation not only of the chemical properties of the elementary bodies but also of a number of their physical prop-

erties such as the composition of the luminous rays they are capable of emitting under definite conditions, for instance, when they are heated to incandescence.

There is one point which we must note. In order to develop in a satisfactory manner this theory of an atom similar to a solar system, Bohr had to introduce a strange idea which he united with the theory of quanta earlier developed by Planck. I have just indicated that in the experiments where we can follow the motion of an electron, the latter behaves like a small corpuscle of very small mass and that its motion can be predicted by the laws of classical mechanics. But let us take into consideration the movements of an electron in trajectories of very small dimensions—motions which we can not follow in detail in experiments but which we needs must imagine in developing certain theories and explaining certain facts. Planck found by his calculations that such movements could not be predicted only from the laws of classical mechanics. To be more definite, among all the motions predictable in ordinary mechanics, only certain ones could be followed by the electron; these privileged ones having been designated "quantized orbits." In his theory of a solar-modeled system, Bohr found it necessary to add this idea of Planck, for in the atoms the trajectories of the planetary electrons are necessarily of very small dimensions. He found that the electrons could execute quantized orbits only; in a manner this circumstance gave the key to all the atomic properties.

Let us summarize briefly what we have said. The study of the properties of matter has led physicists to think of it as formed of little corpuscles—electrons and protons. Various assemblages of these corpuscles form the atoms of the 92 simple elements; from these are formed the composite bodies; in turn, from the latter is made all matter, which therefore is composed of corpuscles of known mass and charge and which in their movements obey the laws of classical mechanics.

However, when we consider movements taking place on a very small scale, the corpuscles seem incapable of making most of the movements which the laws of classical mechanics would authorize. They can take only certain quantized paths. This odd circumstance warns us that it is doubtless insufficient to consider the ultimate elements of matter, the electrons for example, as being merely small corpuscles. This manner of considering the electrons must be modified and completed in a way suggested by certain light phenomena. Accordingly we must turn our thoughts to some phenomena concerning light.

Light which comes to our eyes from the sun or the stars has traversed immense space where matter is absent. Light passes without difficulty through a vacuum and, differently from sound, is not

bound up with matter. Our conception of the physical world therefore will not be complete unless another phenomenon independent of matter be added to it, namely, light.

But what is light? Of what is it constituted?

The philosophers of antiquity and many scientists up to the beginning of the last century maintained that light was made up of small corpuscles in rapid movement. The propagation of light in straight lines under usual conditions, as well as the reflection of light by mirrors, was easily explained by such an hypothesis.

The corpuscular theory of light had been abandoned for a century following the experiments of Young and Fresnel. Young and Fresnel had discovered a large class of light phenomena—those relating to interference and diffraction—the interpretation of which was impossible by the corpuscular theory. However, another conception, the wave theory of light, as Fresnel admirably showed, explains both the older class of phenomena—the rectilinear propagation of light, its reflection and refraction—as well as the later class connected with interference and diffraction.

The undulatory conception of light had been upheld previously by certain farseeing geniuses like Christian Huyghens, who thought that light should be compared to the propagation of a wave in an elastic medium; for instance, like the movement of a ripple upon the surface of a sheet of water upon which a stone has been cast. Since light passes through a vacuum, Fresnel imagined a sort of subtle medium, the ether, which impregnated all matter, filling the empty spaces and serving as a basis for the propagation of the luminous wave.

Let us now consider how a luminous wave is conceived. Light freely propagated is analagous to a succession of waves of which the crests are separated by a constant distance called the "wave length." A group of these waves moves in the direction of propagation with a definite velocity known as the "velocity of light." For light waves in vacuo this should be taken as 300,000 km./sec., as has been measured by experiments made since the death of Fresnel. At any given point in space the different waves with their crests and troughs pass successively. The magnitude which is propagated by the waves therefore varies at a given point periodically and the period of that variation is evidently equal to the time which elapses between the passage of two successive crests.

We have just seen how a wave moves forward in a region where there is nothing to hinder its progress. A different action occurs when the wave in its motion impinges upon an obstacle, for example, if it encounters a plane surface which stops and reflects it; or if it must pass through apertures pierced in a screen; or further if it encounters a point which diffuses it. Then the disturbance will be-

have as if deformed, bent back upon itself, so that instead of having a simple wave we will have to deal with a superposition of simple waves. The state of oscillation at any point depends upon the result of the superposition of the various waves, an effect sometimes additive, at times subtractive. If the simple waves are additive, or as we may say, are in the same phase, a very strong oscillation results; if, on the other hand, the waves oppose each other, or, as we may say, there is an opposition of phase, then the resultant vibration will be very small or even possibly zero. Now it can be shown that the existence at a point of concordance or discordance of phase depends essentially upon the wave length of the wave which happens to strike the obstacle. Resuming, the presence of an obstacle disturbs the passage of a wave, causing the appearance of a complicated distribution of vibration intensities depending essentially on the wave length of the original wave. There result the phenomena of interference and diffraction.

If we adopt this idea that light is made up of waves, we are led to predict that if obstacles hinder the free passage of the bundle of rays, then the phenomena of interference and diffraction will make their appearance. Within the region of interference the distribution of light will be complicated but we can easily predict it from the wave length of the light, that is to say, from the color of light employed. Young and Fresnel showed that light exhibits the phenomena of interference and diffraction. Fresnel showed further that the conception of light waves sufficed to explain in every detail all the observed phenomena of interference and diffraction. On the other hand, the theory which considers light as being simple moving corpuscles can not lead to the conception of wave lengths and is wholly incapable of explaining interference. Following Fresnel, and during the whole of the last century, the undulatory conception of light was admitted without opposition.

You know there exist divers kinds of simple light, each corresponding to a definite color. The white light given out by an incandescent body, an electric light, for instance, is made up of a continuous sequence of simple lights of which the colors vary progressively by imperceptible gradations from violet to red, forming what we call the spectrum. The wave theory of light naturally led to the designation of the quality of each component of the spectrum by its wave length; that is, there exists a correspondence between wave length and color. Since interference phenomena depend upon the wave length, they give us a means of measuring the wave length corresponding to each color of the spectrum. And so we have been able to determine that the wave length varies, increasing continuously from the violet end of the spectrum where

it is about 4/10,000 of a millimeter, to the extreme red where it attains a length of 8/10,000 of a millimeter.

There exist in nature other waves analogous to these light waves but to which the eyes are not sensitive. We are able to show their existence by various methods and to measure their wave lengths. They are included under the general designation "radiations," a term which also includes light waves. Certain radiations (ultra-violet, X and $\lambda$ rays) have wave lengths shorter than those of light; others, (infra-red, Hertzian) on the contrary, have longer wave lengths. X rays have wave lengths of the order of 1/10,000,000 of a millimeter. They therefore have a very much shorter length than the visible ones.

Thirty years ago no one questioned the undulatory theory of light. Since then hitherto unknown phenomena have come to light produced by radiations which did not appear to be explainable except by the corpuscular theory. The principal one of these phenomena was the photo-electric effect. Here are its characteristics: When we illuminate a piece of matter, a metal, for example, with either light or X rays, this piece of matter emits electrons, moving more or less rapidly. A study of this phenomenon showed that the velocity of these expelled electrons depends only on the wave length of the incident light or X rays and the nature of the matter upon which this radiation falls. It does not depend upon the intensity of the radiation. Only the number of emitted electrons depends upon that intensity. Further the energy of the expelled electrons varies inversely with the wave length of the incident wave. Einstein, reflecting upon this phenomenon, saw that in order to explain it, it would be necessary to return to a corpuscular structure of light. He supposed that the radiations are made up of corpuscles transporting an energy inversely proportional to the wave length of the light and showed that the laws of the photo-electric effect can be readily deduced from such an hypothesis.

And so it came to pass that the physicists were much embarrassed, because on the one hand there was a class of phenomena, the phenomena of interference and diffraction which indicated that light must be made up of waves, and on the other hand there was the photo-electric phenomenon, as well as other evidence, which as insistently indicated that light must be made of corpuscles or "photons" as they are now called. The new corpuscular theory of Einstein defines the energy of a light corpuscle in terms of a wave length, which is foreign to the idea of a strictly corpuscular radiation.

The only way to escape from this difficulty is to admit that light is formed of waves and corpuscles so closely bound together that they behave as two complementary aspects of reality. Each time that

a radiation exchanges energy with matter, the exchange can be described as being an absorption or emission by the matter of a photon, and when we wish to describe the movement in space of corpuscles of light we must speak of the propagation of a wave. Elaborating further this conception, we are led to admit that the density of a cloud of corpuscles, which constitutes a luminous wave, is always at every point equal to the intensity of the associated wave. It thus happens that we come to the synthesis of two old rival theories of light. We thus explain at the same time both the interference phenomena and the photo-electric effect. Great interest lies in this synthesis because it indicates to us that in nature both light waves and the corpuscles of matter are intimately connected, at least in the case of light. But if this is true with light, may we not also expect it to be true with matter? Until now all the efforts of physicists have tended to reduce matter to a complicated structure of corpuscles, photons, and electrons. But just as a photon can not be conceived without its wave which travels with it, should we not also suppose that the corpuscles of matter are always escorted by a wave? Such is the leading question now asked of us.

Let us suppose that a corpuscle of matter, an electron, for example, is always accompanied by a wave, the corpuscle and the wave being intimately bound together. The movement of the corpuscle and the propagation of the wave are not independent, and we should be able to obtain a relationship between the mechanical magnitude of the corpuscle—the velocity and the energy—and the magnitude characterizing the wave—the velocity of propagation and the wave length. In suggesting the connection which should exist between the protons and their associated light waves, we can indeed establish a parallelism. This theory of the bond between the material corpuscles and their associated waves is to-day know as wave mechanics. Naturally I can not to-day lay before you the details of this mechanics. I will limit myself merely to telling you that it leads to attributing a wave length to the wave associated with the material corpuscle, a value which varies inversely with the velocity of the corpuscle. The more rapidly the corpuscle moves, the smaller is the wave length of the associated wave.

When the wave moves freely in a portion of space whose dimensions are large compared with the wave length, the new mechanics attributes to the associated particle a movement identical with that predicted by the classical mechanics. There is therefore here an accordance between the old and the new mechanics. Particularly is this the case with the electrons which we can observe directly, and we thus explain why the study of the electron movements on a large scale led to considering them as simple corpuscles moving according to the laws of the classical mechanics.

But we meet with two cases where the laws of classical mechanics fail to predict the movements of the corpuscle as will the new theory. The first case is where the propagation of the associated wave is limited to a region of space of which the dimensions are of the order of magnitude of the wave length. This occurs for an electron in the interior of an atom. The wave associated with the atom is then obliged to take the form of a stationary wave analogous to the elastic stationary waves which may occur in a cord fixed at both ends or the stationary electric waves which form in the antennae used for wireless telegraphy. Theory shows that these stationary waves can take only certain well-defined wave lengths corresponding to certain definite movements of the associated electron. These movements are precisely the quantized states introduced by Bohr in his theory of the atom and we now have an explanation of the hitherto very mysterious fact that these quantized states are the only possible ones for an electron bound to an atom.

There is a second case where the movement of the electrons, according to the laws of the new mechanics, should not obey the laws of the classical mechanics. This is where the associated waves strike an obstacle in the path of propagation. Interference phenomena are then produced and the movements of the associated corpuscles are no longer what would be expected from the classical mechanics. In order to render an account of what takes place, let us be guided by an analogy with radiations. Let us imagine that we observe a radiation of known wave length with a contrivance capable of showing interference upon a screen. Since we know that the radiations are formed of photons, we can just as well say that we see a swarm of photons upon the screen. In this conception, in the places where interference takes place, the photons arrange themselves in such a manner that they become concentrated where the light intensities are the greatest. If we now send upon the same screen, not a radiation but a bundle of electrons of which the associated waves have the same wave length as the radiation previously employed, the waves will interfere in the same manner as in the preceding case since it is this wave length which controls the phenomena of interference. It is therefore quite natural to suppose that the electrons are concentrated there where the intensity is the greatest; in other words, in the new experiment the electrons arrange themselves in space similarly as did the photons in the first experiment. If we can prove that this is indeed the case we would then have shown the existence of a wave associated with an electron and we could measure its wave length, establishing the truth of the fundamental basis of wave mechanics.

Now, wave mechanics leads us to attribute to electrons moving with such speeds as usually occur in our experiments, an associated wave whose wave length is of the order of that of X rays (0.0001

of a millimeter). In order to show the existence of the associated electronic waves, it is necessary to try to realize with them phenomena of interference analogous to those which we get with X rays. Phenomena of this nature have been obtained. The first physicists who succeeded in obtaining such results were Messrs. Davisson and Germer of the Bell Laboratories in New York. But I am not going to describe their experiments; instead I will tell you of the beautiful results, analogous in nature, although slightly different, which were made later by G. P. Thomson in England and by M. Ponte in France, for M. Ponte has had the kindness to lend me the photographs so that I may lay before your eyes the actual results.

When we send a pencil of X rays upon a powder composed of small crystals oriented in random directions the X rays are diffused by the regularly arranged molecules in the small crystals and inter-

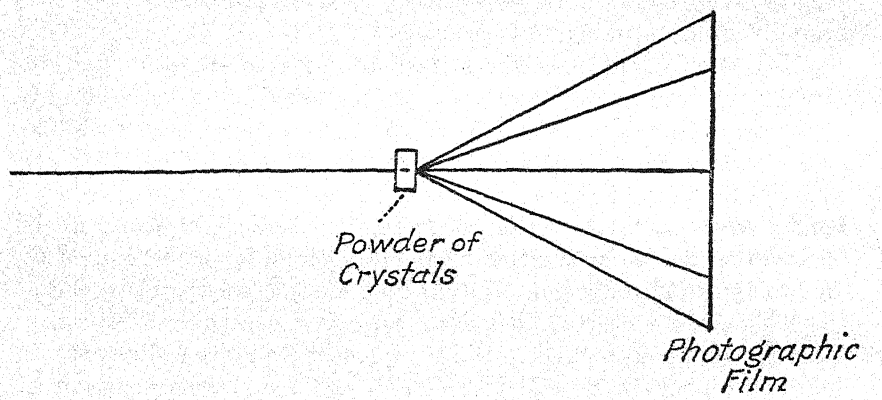



FIGURE 1

ference takes place between the diffused X rays. Theory predicts that if we place a photographic plate perpendicular to the pencil of rays incident upon the plate in the manner shown in Figure 1, the X rays should affect the photographic plate in circles centered upon the direction of the incident ray. Experiment verifies splendidly the prediction and we have upon the plate rings which are black upon the negative itself but white as shown in the positive reproduced in Plate 1, Figure 1.

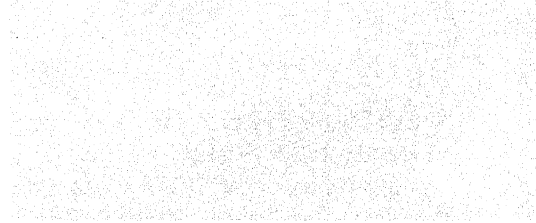
The diameter of the rings depends upon the nature of the crystalline substance employed as a diffusing means and upon the wave length of the radiation. If with the same diffuser we employ X-ray radiations of shorter and shorter wave lengths the system of rings moves toward the center.

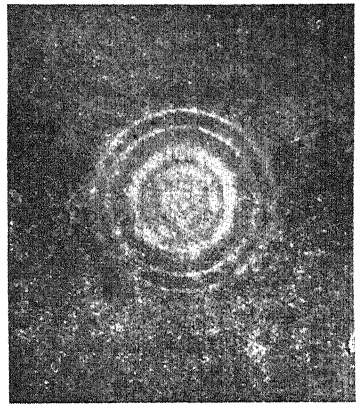
We may employ in the place of the powder of small crystals a very thin metallic plate. The study of the structure of metals has shown that they are formed of a conglomeration of small confused crystals.

The experiments which we have just described, which appear to have been first made by my brother Maurice before the war, are generally known as the experiment of Debye and Scherrer. They prove the wave structure of X rays, but that was already known before these experiments. If now we repeat these experiments with electrons, we would have a proof of the wave character of the electron. This was realized by Messrs. Thomson and Ponte. M. Ponte proceeded as follows: He sent a bundle of electrons upon a film of zinc oxide formed of little crystals of this substance. Then placing a photographic plate as I have described above he obtained photographs such as are shown in Plate 1, Figure 2.

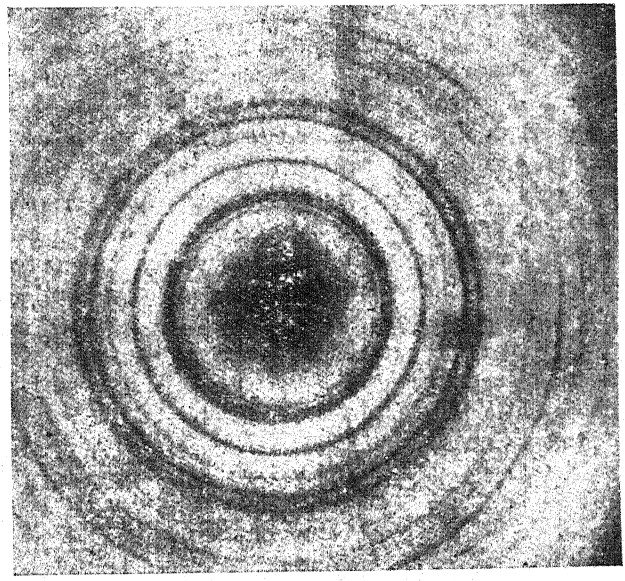
The diameter of the rings corresponds to what was foreseen by the formulae of wave mechanics. These formulae, we have seen, tell us the wave length associated with the electron which is smaller the greater the velocity of the electron. Therefore, if we first send upon the zinc oxide screen electrons having a certain velocity, we obtain a definite system of rings (pl. 2, fig. 1); if next we send electrons of greater speed, we obtain a similar system of rings but moved further in towards the center (pl. 2, fig. 2). The correspondence with the predictions of wave mechanics is quantitative with an accuracy of at least 1 per cent.

The experiments of Davisson and Germer, of G. P. Thomson, of Ponte, and of others, have proved that the electron is not a simple corpuscle; it is at the same time a corpuscle and a wave. It is doubtless the same case with the proton as all recent experiments seem to prove. As matter seems to be formed of protons and electrons, we see that matter, like light, is made of corpuscles and waves. Matter and light thus appear to be much more similar than we had supposed only a very short time ago when we considered matter as being composed of corpuscles only. Undulatory mechanics has thus embellished and simplified our conception of Nature. Further it has led us to predict interference and diffraction phenomena with electrons of which I have just shown you the experimental proofs. One can say then that an important step has thus been taken along the road which little by little leads the human mind to a more exact knowledge of the secrets of Nature.

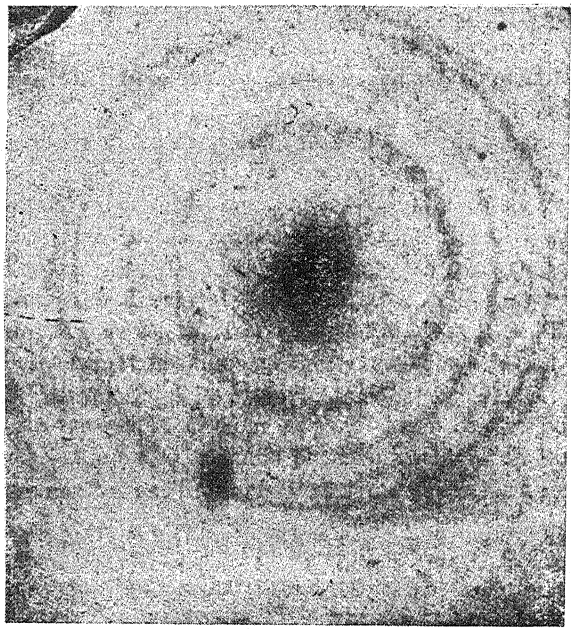




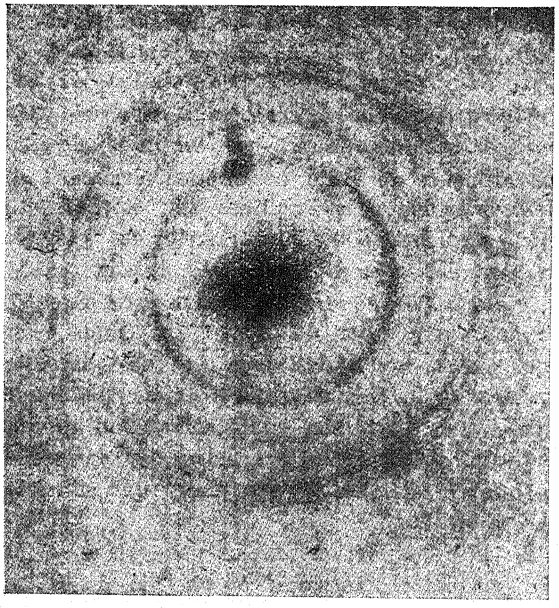
1. INTERFERENCE OF SCATTERED X RAYS



2. INTERFERENCE OF SCATTERED ELECTRONS



1. RINGS FORMED BY SCATTERED ELECTRONS (SLOW)



2. RINGS FORMED BY SCATTERED ELECTRONS (FAST)

# NEW RESEARCHES ON THE EFFECT OF LIGHT WAVES ON THE GROWTH OF PLANTS

By F. S. Brackett and Earl S. Johnston

[With 3 plates]

One of the most commonly observed relationships between plants and light is that of phototropism, or the directional growth of plant organs as influenced by light. A potted plant, such as the geranium, placed on the window ledge where light will fall on it from one side will, in a comparatively short time, turn its leaves in a position to receive maximum light from outside the room. The beautiful symmetry of plants is very easily lost when they are exposed to unilateral illumination.

Various parts or organs of plants respond differently to light. Young shoots and leaf petioles usually grow toward the source of light, while the leaves frequently set themselves at right angles to its beams. Occasionally there are organs which grow away from the source of light. These three types of growth are known respectively as positive, transverse, and negative phototropism. One of the few plants which shows all three types of phototropism is the mustard seedling illustrated in Plate 1. A 200-watt electric lamp served as the light source in this particular case. The direction of the light is indicated by the arrow. The shoot shows positive phototropic bending, the roots negative, and the small leaves distinctly show a tendency to expand at right angles to the beam of light.

Light has a threefold effect on plants. The plant's response to a bright light is different from that to a dim light. Chlorophyll, the green pigment, is formed in the presence of light, but if the light is very intense, this coloring matter is destroyed. The number of hours per day that the plant is exposed to light governs to a large extent the nature of its growth. The very interesting and extensive experiments of Garner and Allard of the United States Department of Agriculture have conclusively shown that plants may be made to grow vegetatively, or to set flowers and fruit, merely by changing the length of time they are exposed to light. The color, or wave length of light, also plays an important part in the plant's behavior. Chlorophyll formation will be more rapid in red than in blue or violet light. On the other hand, the short wave lengths at the violet

end of the spectrum have the greatest retarding effect so far as the rate of stem elongation is concerned. Thus, plants grow and develop differently in accordance with the intensity of light, its duration, and its color.

The three light variables just mentioned, which influence the general character of growth, likewise should be considered in the specific case of phototropism. In many of the early experiments dealing with the bending of plant stems toward light sources, the lights used were such that it was impossible to determine accurately whether it was the color or the intensity of the light that was causing the bending. To be sure, both these factors of light influence this one-side growth response, but the relative influence of the different colors, or wave lengths of light, could not be determined because of the different intensities of the colors used. In order to determine which colors are most effective in phototropic bending it is necessary to use wave lengths of known intensity. With the object of determining in a quantitative way some of the fundamental growth responses of plants to light, the Division of Radiation and Organisms of the Smithsonian Institution has initiated a series of experiments which will eventually clarify this problem. Before describing the methods used in eliminating the intensity from the wave-length effect of light on growth, it may be well to examine briefly the mechanics of phototropism.

About 100 years ago De Candolle, the Swiss physician and botanist, thought that positively phototropic bending was due to the retarding effect of light on growth. The side of the stem most brightly illuminated would grow slower and bring about a bending toward the light source. The enormous elongation of potato sprouts in a darkened cellar would seem to substantiate the view that plant stems grow longer in the dark than in light. Thus the shaded side of the stem of the geranium plant growing by the side of a window will elongate more than the side more brightly illuminated. The result is obvious. The stem and the petioles bend toward the window. Mature plant tissues that have almost completed their growth cycle do not show this bending nearly so much as young tissues. Only the tissues that contain cells still capable of dividing or of enlarging are the ones concerned in this phenomenon.

Objections were made to this early view of phototropism. Such distinguished men as Darwin and Pfeffer, the noted German plant physiologist, were led to believe that there existed a region in the plant capable of receiving a stimulus and that such a region was more or less localized. In one experiment the apex of a young sprout was exposed to light while the bending occurred at the base which was not illuminated. It thus appeared that in addition to a region of perception, there was a region of response. If this were true, then

the tissues between these two regions must be capable of conducting the excitation from the former place to the latter. It would appear on first sight that a plant is very much like an animal which, for example, sees food with its eyes. The excitation travels over the nerves to the legs which react in such a manner as to carry it toward the food. In a growing shoot, the tip perceives light on one side. The sensation is transmitted to the part lower down where differential growth goes on in such a manner as to point the stem or shoot toward the light.

A good deal of work on phototropism has been done with the coleoptiles of plants belonging to the grass family. The coleoptile is a leaf sheath surrounding the plumule or bud of the ascending shoot or foliage leaves. The oat is a favorite plant for such experiments. One ingenious experimenter as recently as 1910 hit upon the unique idea of cutting off the top of a coleoptile and sticking it back on the stub with melted gelatin. When the tip was illuminated on one side the shoot still showed marked phototropic bending at the base. Did the stimulus received by the tip travel to the base after passing through a layer of gelatin? This experiment stimulated much interest and many curious methods were devised for decapitating the coleoptiles and replacing their "heads" in various positions. Further interesting experiments are reported in which the "heads" of coleoptiles illuminated from one side were cut off and stuck on the stumps of decapitated coleoptiles grown in the dark. These "doctored up" coleoptiles when allowed to continue their growth in the dark showed positively phototropic curvatures in the proper direction.

Professor Priestley, of England, has recently been studying these very interesting plant traits and has done much toward giving this peculiar phenomenon a rational explanation. He shows that phototropic curvature in coleoptiles is consistent with the "light-growth" hypothesis in spite of many seemingly discrepant experiments. The amount of light required to induce phototropic curvature in normal light-grown shoots is greater and must be continued longer than that required to bring about similar curvatures in etiolated shoots. Etiolated shoots are those grown in the absence of light. Such plants are white or pale in color and usually differ from normal plants in the structure of their tissues. Light affects normal and etiolated shoots quite differently as will be shown.

It is well to pause at this point to consider a few essential conditions for growth. The meristematic tissue consists of a group of actively dividing cells. An available water and food supply is necessary for this kind of growth. Extending up and down plant stems are tiny tubes through which water and solutions of food material pass. In order that these materials, so essential for

growth, reach the cells located at a distance from the main trunk lines, it is necessary for them to pass through the walls of the intervening cells. The more permeable these walls are to water and the foods dissolved therein, the better are the chances for rapid growth of the meristematic tissues. Wilted plant cells can not grow. Growth ceases even when the cells just begin to wilt. Cells stop growing when they lose water faster than they can absorb it or when they can not get a sufficient amount because of a blockade in the line of cell walls connecting them to the water mains (vascular tissue). The entire system is very delicately balanced.

How is this sap or water system related to phototropic bending? As Professor Priestley states, "In this delicately balanced equilibrium, strong lateral illumination may mean that the sap supply first fails on the side more directly lit, where evaporation will more rapidly bring about a state of 'incipient drying' in the walls of the tissues. * * * If the walls between the vascular supply and superficial meristem are in this condition, food supplies to the meristem will fail, and there will be a cessation of meristematic growth." Less growth will occur on the drier or more illuminated side. This will result in a positively phototropic bending.

In etiolated shoots the mechanism of bending is quite different. Very little light will cause marked growth curvatures, whereas with shoots previously illuminated a stronger light is necessary. The walls of the cells making up the tissue in etiolated shoots contain fat and protein, a substance similar to egg white. These substances prevent the ready passage of sap and water from the vascular supply to the meristematic tissue, which, under favorable conditions, is capable of rapid growth. Blaauw, a Dutch scientist, points out the similarity between light in its photochemical effect on a photographic plate on the one hand, and on an etiolated coleoptile on the other. Relatively small quantities of light produce a photochemical action in these shoots. Protein and fatty materials disappear from the cell walls, the latter substances migrating mainly to the cuticle. The passageway between the meristematic cells and their water and food supply is opened up. In the words of Professor Priestley, "Increased superficial growth now ensues. Growth as a whole may be as active as ever on the more brightly lit side of the etiolated shoot, but it is differently distributed. More cells are added to the surface of the stem and leaf, and less proportionately contributed to the inner layers of the shoot axis. The result is, therefore, in the aggregate, a retardation of growth in length on the illuminated side and a positive phototropic curvature."

Although many roots are not sensitive to light there are a few, as previously mentioned, which show negative phototropism. The section of the root capable of bending is situated just back of the

apex or tip. In this region the cells are rapidly enlarging by taking in water. The water fills up a space in the cell's interior called the vacuole. Such vacuolating cells grow rapidly by enlarging. In their earlier stage, when forming the meristematic tissue, growth proceeded by rapid division of the cells. Negative phototropic bending of these roots is attributed to the increased rapidity with which these vacuolating cells enlarge under the influence of light. Those on the shaded side of the root enlarge less rapidly.

On the basis of the above theory it may be worth while to examine the results obtained with decapitated coleoptiles. These organs, at the stage they are used in such experiments, grow entirely by cell enlargement and not by cell division. Light increases the rate of cell enlargement but the final size is less. The veins or water pipes running to the tip of the coleoptile, terminate in a pore. When the shoot becomes gorged with water this pore serves as a safety valve and frequently a drop of water is seen on the tip of this shoot. If the water pressure is decreased in the pipe line on one side, growth on that side is retarded. Light, by its photochemical action on the proteins and fats, makes the passage of water through the coleoptile tissue comparatively easy, hence when one side is illuminated the flow of water through the vein in that region is facilitated, thereby reducing the turgor or water pressure. This in turn retards growth on the brighter illuminated side. On the less lighted side growth is faster. This causes the shoot to bend toward the light. By cutting off the tip, water is freely lost and growth retarded. Now if half the stub is covered so that the veins in that region are blocked, bending due to increased rate of growth will occur even in darkness in such a manner that the blocked veins are on the convex side of the curved shoot. It seems a likely hypothesis that the mechanics of phototropism is a light-growth reaction based to a large extent on the relation of growth to available water and food supply.

There is little doubt but that the wave length, or color of light, is an important factor to be considered in a study dealing with fundamental problems of plant growth. Since it appears that phototropism is a specific case of light-growth reactions, it is believed that some of the underlying principles relating to the growth of organisms, especially plants, can be worked out from accurately controlled experiments dealing with phototropic responses of etiolated shoots. Such shoots are extremely sensitive to light of relatively low intensity and short exposure. Before the wave-length effects of light can be determined accurately, it is, of course, necessary to eliminate all intensity effects. This phase of light and growth is one of the problems being investigated in the laboratories of the Smithsonian Institution.

For this purpose a wooden light-proof box, 7 feet 10 inches long and 12 inches wide, was built. This box was divided into five compartments or separate chambers. The two end compartments containing the light sources were approximately 27 inches high, or 5 inches higher than the other three. The central, or plant compartment, was 2 feet 10 inches long. Between the central and the end chambers were partitioned off two small compartments containing ray filters and the water and air cooling devices. This apparatus, the plant photometer, is illustrated in Plate 2.

Briefly, the method of carrying out this experiment is to place, for example, a yellow ray filter in one end of the central or plant chamber and a green one in the other end. The intensities of the lights coming from the lamps in the end chambers were so adjusted that they register the same intensity on a delicate thermocouple placed at the center of the plant compartment. After the proper adjustment had been made the light measuring apparatus was removed, as illustrated in the picture, and the seedling of an oat plant placed in the chamber. The seedling was placed in a vertical position and surrounded by a rotating double-walled glass cylinder. This cylinder, rotating slowly around the seedling, insures equal temperature and moisture conditions in the immediate vicinity of the plant. This precaution is necessary since slight differences of temperature or moisture will cause unequal growth in the side of the stem and bring about a curvature.

After the seedling has been properly adjusted between the yellow and green lights of equal intensity, the box is closed and the plant permitted to grow from two to four hours. When the plant was examined in this particular experiment, it had grown toward the green light somewhat in the manner of the seedling illustrated in Plate 3. Thus, of the two colors of equal intensity used in this experiment the green was more effective in retarding growth, as was evident from the plant's bending toward that light.

In order to evaluate the effect of one color in terms of another, other experiments were carried out after changing the relative intensities of the two lights. Intensities were finally reached at which the plant grew without bending toward either light. The intensities were then measured, and it was found that the yellow light was approximately 1,000 times as intense as the green at the balancing point. The light passing through the blue ray-filter used in these preliminary experiments exerted a greater growth-inhibiting influence than either the yellow or green lights, the factor being 30 when compared with green or 30,000 when compared with yellow, assuming a linear intensity effect. We see, therefore, that the effect becomes much more pronounced as we shorten the wave length.

In order to more completely describe this increase of phototropic effect with decrease in wave length, that is, in passing from red to

yellow, yellow to green, and green to blue, it is desirable to expose the plant to a narrower wave-length band. If we look at white light as it is spread out into the spectrum by a prism, we see that the red changes gradually into yellow, the yellow into green, and green into blue, and that an indefinite number of different pure colors actually exists. By using an instrument called a monochrometer, it is possible to select a more definite shade of yellow or green, and instead of using just three wide color bands, we could divide the spectrum into 50 or 100 purer colors or bands, of more restricted wave-length range. If we plot, then, the intensity of each shade required to balance the phototropic influence of a given standard lamp against the wave length, we can obtain a group of 50 or 100 points instead of the three obtained in the preliminary experiment. The equipment for this more elaborate undertaking is under construction.

In the general study of the very complicated phenomena of plant growth, light enters as an important factor in many ways. Supplying, as it does, the necessary energy for the process of converting carbon dioxide into sugars and starches, its relation to this process, termed photosynthesis, is one of greatest interest. As the energy which we derive from our food was originally stored up by this process of photosynthesis, an understanding of the process is of the greatest importance to our existence. Experiments are being undertaken, designed to study the effect of different colors of light upon plant growth, together with observations as to the amount of carbon dioxide utilized under rigidly controlled conditions. In these experiments nutrient solutions instead of soil are used because of their reproducibility. Lights similar to Neon signs, but yielding more nearly a single wave length, replace the usual sunlight. It is hoped that these experiments will throw some light upon the little understood process of photosynthesis.

Among the difficulties which face the experimenter in studying these phenomena is the fact that he does not know the construction of the very complicated molecules which are present in living tissue. Chemical analysis yields information as to the elements which make up these complicated molecules, but the usual methods of observation do not offer enough data for determining the position of the various atoms, or the forces which hold them together. Study of the light which such molecules emit or absorb offers a wealth of new data which may serve as a key to a more complete understanding of those molecules which are of pivotal importance. In order to understand how such information can be gained, it may be well to make some simple comparisons. When we hear a sound we are immediately able to say that the source of the sound is a bird, a whistle, or a horn, as the case may be. We do so by associating the characteristic

pitches, frequencies or wave lengths of the sound with the source. In the same way, the frequencies or wave lengths of light emitted or absorbed by a molecule are characteristic of the molecule, and are determined by its construction. To get the most information about the characteristics of the sound and relate these characteristics to the construction of the source of the sound, the ear is inadequate, and an apparatus must be provided for determining just what frequencies or wave lengths are present. So in the study of light we must have a machine which will distinguish between the different wave lengths, or colors, in a more quantitative fashion than the eye is capable of doing. Such an instrument is known as a spectrometer. Looking into a spectrometer we see the light spread out into its constituent colors, the red on the left and the blue on the extreme right, with all the intermediate wave lengths or colors arranged between them in an orderly fashion. Unfortunately, the light which gives the most information in regard to these large complicated molecules is of too long wave lengths to be seen by the eye. It is necessary, therefore, to substitute for the eye a very sensitive electrical thermometer. By turning a single dial successively different wave lengths are caused to fall upon this sensitive thermometer, which by its change in temperature, records the amount of each wave length present.

A spectrometer is very similar in its analysis of light to a radio receiving set in its analysis of the electrical oscillations which it picks up. As one turns the dial slowly, the instrument responds first, say, to 200 meters, then to 201, 202, and so on to the other extreme of its range, say, 800 meters. If a station is broadcasting on a wave length of 304 meters, as one comes to the dial number 302 he begins to hear it. It comes in strongly at 304, and fades out at 306. The range over which it may be picked up on the dial is associated with the selectivity of the set. In the same way a spectrometer responds to the different wave lengths of light. If a single strong wave length is being " broadcast " by a mercury arc, and that wave length is $1\mu$, or one-millionth of a meter, the spectrometer will pick it up weakly at a dial reading a little less than $1\mu$, show a maximum response at $1\mu$, and as one continues to turn it, gradually lose it as $1\mu$ is passed. The range over which it responds depends upon its selectivity, or resolving power. As a matter of fact, the mercury arc broadcasts not simply on one wave length, but on several, so that as one turns the dial, he picks it up at several different points. The accompanying illustration, Figure 1, shows the different wave lengths of radiation received from a mercury arc. The widths of the bases of these peaks depend upon the selectivity, while the heights indicate the intensity or strength of the signal. If the selectivity were less the bases would be broader, and the signals of very nearly the same wave length would be confused and not observed as a separate effects, just as in a poor radio one gets several

stations coming in at once. The construction of such an infra-red receiving equipment or spectrometer which will automatically record the intensities of radiation of different wave lengths upon a moving photographic plate is a part of the program. One such instrument to be used in the range of wave lengths between 1$\mu$ and 2.5$\mu$ or between 1 and 25 millionths of a meter is already completed and in operation. Other machines to operate in the region between 2$\mu$ and 15$\mu$ are under construction.

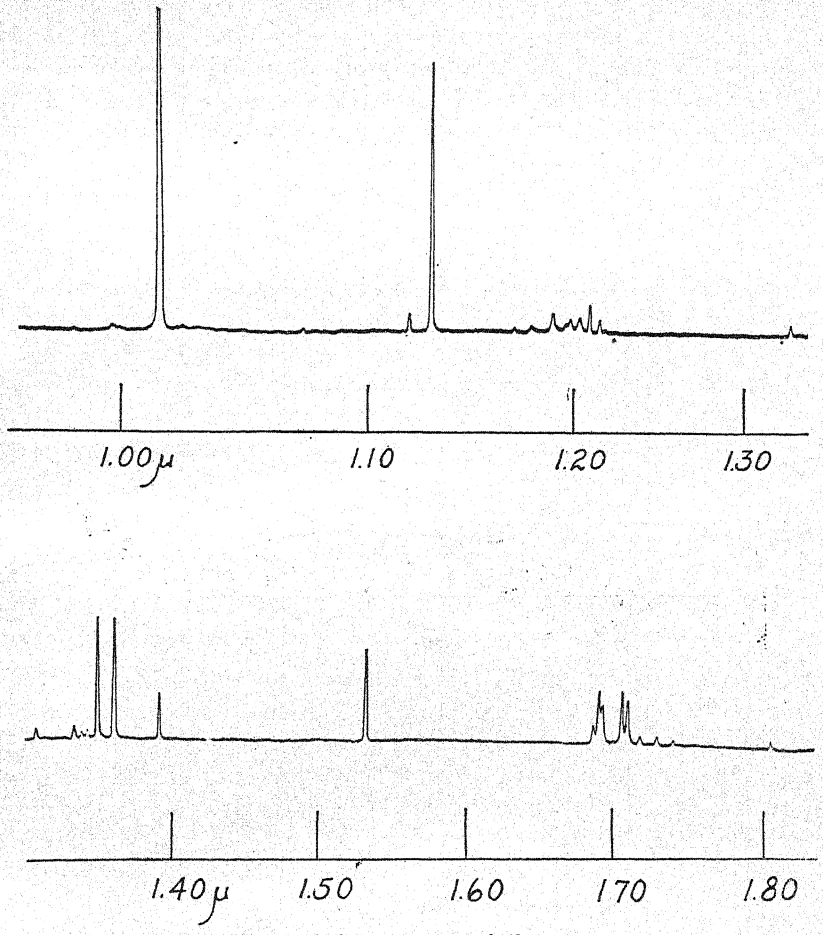



FIGURE 1.—Emission spectrum of the mercury arc

Molecules not only emit frequencies which are characteristic of them, but also when light is passed through them, absorb through resonance the same frequencies. Often it is more convenient to study their absorption than their emission. Thus light may be taken from an ordinary tungsten Mazda bulb, passed through a liquid, the structure of whose molecules is to be studied, and analyzed to see what frequencies have been weakened. The top curve of Figure 2 shows the light from a Mazda bulb passed through 1 cm. of carbon

tetrachloride. As carbon tetrachloride is practically transparent in this region, all frequencies of the range are present in considerable strength. The second curve shows the effect of adding 0.127 grams of paradichlorbenzene. Here it will be noticed that frequencies in the region of 1.13$\mu$ and 1.66$\mu$ are much weaker, those being the characteristic frequencies absorbed by the paradichlorbenzene. The other curves show successively greater concentrations of paradichlorbenzene. It will be noticed that the weaker absorption frequencies are more clearly evident in the greater concentrations. By comparing the characteristic frequencies absorbed in paradichlorbenzene with other halogen derivitives of benzene, important information can be gained in regard to the structure of these interesting molecules. This type of study will eventually be extended to molecules which are of importance in the biological processes.

While it is possible, through direct observation of complicated living organisms, to accumulate a vast amount of valuable informa-

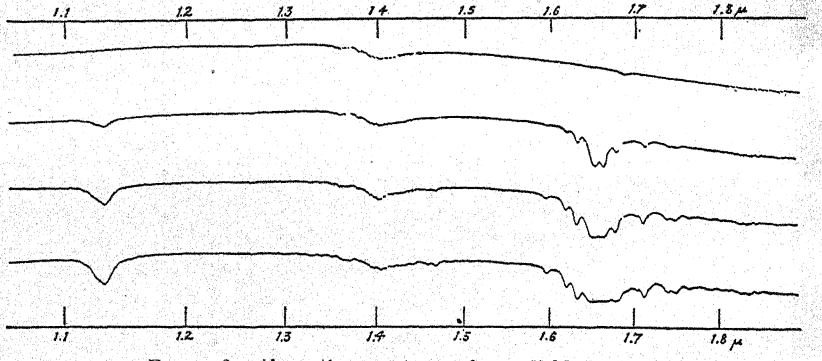
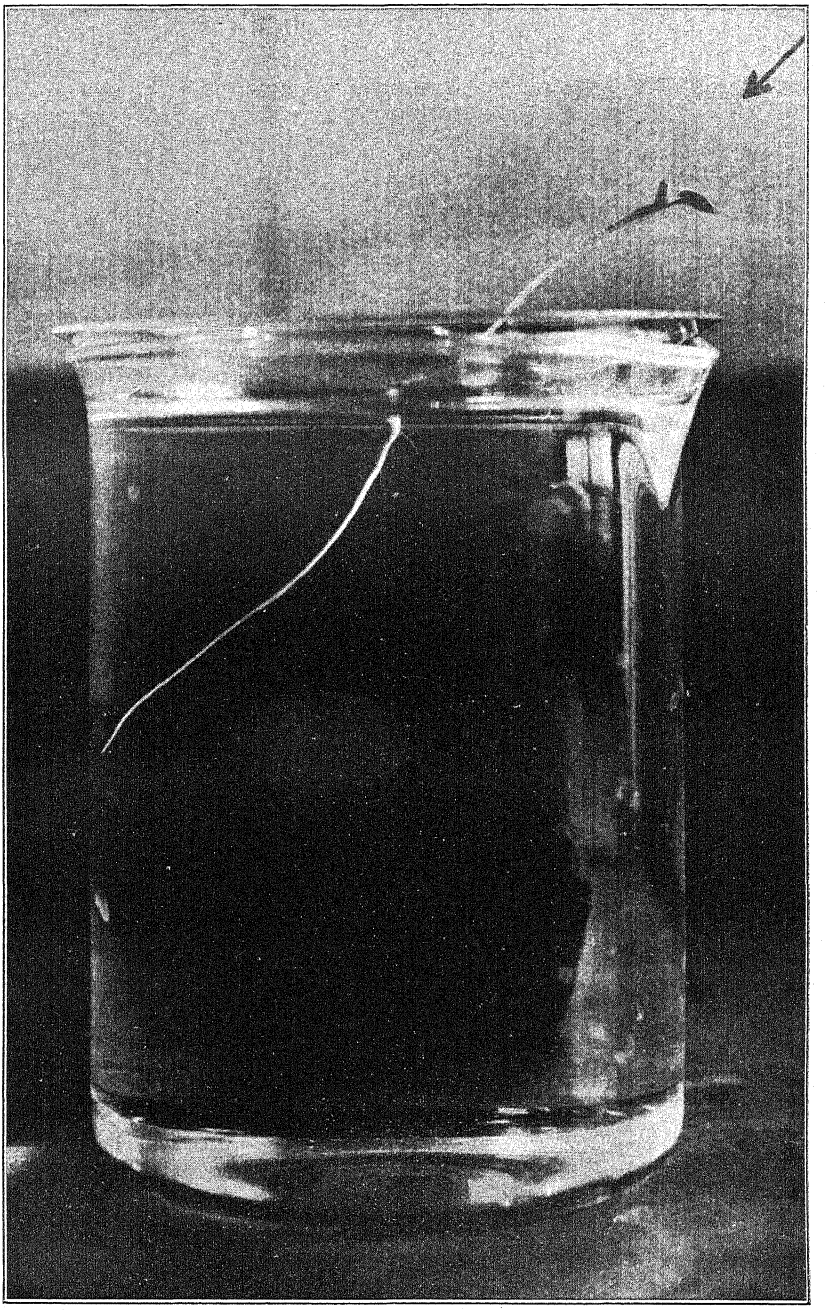
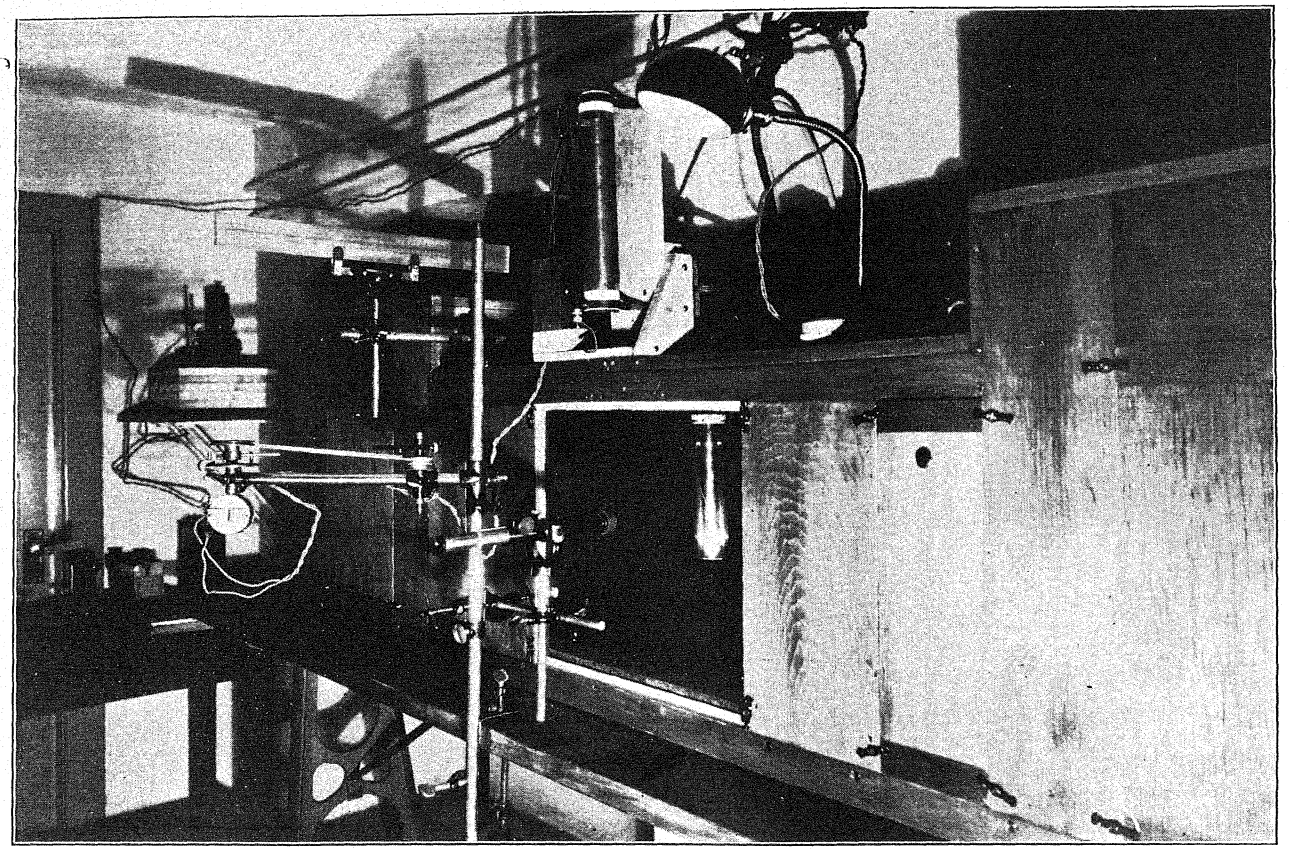



FIGURE 2.—Absorption spectrum of paradichlorbenzene

tion, complete understanding of the processes which are involved is impossible without a knowledge of the structure and characteristics of the molecules entering into these processes. Most of the molecules, such as those of chlorophyll, the various proteins, and enzymes, are so complicated as to render it impossible to gain even the customary chemical knowledge derived from analysis and synthesis. Real understanding requires not only this information, but a knowledge of other physical characteristics which determine the nature of their chemical reactions and their responses to various wave lengths of light. The most logical hope of progress in studying these very complicated molecules is to bring to bear those methods which yield the greatest amount of independent data. The type of investigation just described is one of the most promising approaches which has offered itself. Thus these types of research which, at first glance seem remote from biology, should, in the long run, prove of the greatest value in gaining a fundamental understanding of these biological processes which are of such vital importance.



MUSTARD SEEDLING GROWN UNDER THE INFLUENCE OF UNILATERAL ILLUMINATION. THE DIRECTION OF THE LIGHT IS INDICATED BY THE ARROW



PLANT PHOTOMETER USED TO DETERMINE THE RELATIVE EFFECTS OF DIFFERENT COLORS OF LIGHT ON PLANT GROWTH



AN OAT SEEDLING SHOWING PHOTOTROPIC BENDING AS A RESULT OF DIFFERENCES IN WAVE LENGTHS OF LIGHT ILLUMINATING IT FROM OPPOSITE SIDES

# THE AUTOGIRO: ITS CHARACTERISTICS AND ACCOMPLISHMENTS[1]

By HAROLD F. PITCAIRN
*President, Pitcairn-Cierva Autogiro Company of America*

[With 9 plates]

To reach a correct understanding of the Autogiro and the principles which underlie its performance, I feel that it will first be necessary to tell something of the man who has invented the most remarkable aircraft known up to this time.

Señor Juan de la Cierva is a Spanish gentleman of great personal charm and brilliance. In his own land he is a person of real consequence. On the technical side, his genius undoubtedly places him among the world's foremost mathematicians.

His democratic manner, kindliness, and tirelessness in his work have brought him the respect of all with whom he has come into contact, and although he has received some of the highest of the world's honors, he is among the plainest of men in his ways. He is a tremendous worker; the present degree of perfection to which he has attained in the Autogiro is due, almost in entirety, to his efforts alone. He had faith in the principle which he first brought forth, and in the face of many disappointments, due to machines which refused to leave the ground, he persevered in his efforts until the Autogiro has finally proven practical and safe.

In his boyhood, Cierva, with two friends of his own age, built and flew kites and gliders. Progressing further, they built, or rather rebuilt, a power plane which flew more successfully than when new. In 1912 a French pilot brought a French biplane to Madrid for exhibition flights. People then were not as accustomed to airplanes as they are now, and when this pilot landed the crowd rushed in upon him, with the result that there was a serious accident. The machine was completely wrecked, although the pilot himself was unhurt.

Later, Cierva and his young friends approached the pilot with the novel offer that they would rebuild the plane if he would test

[1] Presented at the stated meeting of the Franklin Institute held Wednesday, Nov. 20, 1929. Reprinted by permission from Journal of the Franklin Institute, vol. 209, No. 5, May, 1930.

fly it. Thinking it more a joke than anything else, the pilot accepted. There was practically nothing salvageable about the machine excepting the motor and the wheels. With these as a basis, the boys set energetically to work.

The carpentry shop of one of their fathers was open to them and, doing all the intricate work of fitting bits of wood and stretching canvas, they turned out a machine which flew decidedly better than the original. This machine was the first in Spain.

Later on, in 1913, they started to build a racing plane. In this they had at first the support of their people, who were encouraged to help them because of their initial success. However, in striving after speed, the boys gave their monoplane so little surface that it could scarcely get off the ground. After several minor taxying accidents in which undercarriages gave way, their parents' confidence waned and the boys were compelled to give up the project.

All this amateur experimentation had given Cierva the feel of the air and the conviction that his future career lay in aeronautics. Upon his return to school at that time, which was about at the beginning of the World War, he elected to take an eight years' course covering civil and mechanical engineering, since that was the nearest approach to an aerodynamic engineering course available. At that time there were no schools of aerodynamics in Spain. During his school career he always stood well near the head of his class.

I wish to emphasize that it was Cierva's thorough grounding in engineering and mathematics which enabled him to work out in theory alone the invention of the Autogiro. It was the result of tireless effort and endless patience, and was achieved along logical, constructive lines. The invention was not a haphazard one.

Toward the close of the World War, the Spanish government announced a competition for the design of three types of military planes. These were pursuit, reconnaisance, and bomber. In a sporting spirit, Cierva entered the design competition for the bomber, and produced a plane which in many respects was years ahead of its time. When he designed it, the warring countries still withheld all information on design, so that the machine could truly be called his own. It was a 3-motored tractor biplane, with a wing span of around 100 feet. At that time there were no other 3-engined machines excepting the Caproni, and that was not of the modern tractor type.

The machine proved entirely successful. Cierva's test pilot, distinctly scared by its great size, treated it with great gentleness at first, but as he found it responsive and maneuverable, his fears diminished and overconfidence set in, with the result that he flew it in a way that no big machine could be handled, and while flying near the ground, stalled and crashed. He was only bruised, but the machine was demolished.

The accident caused Cierva to review the entire progress of mechanical flight. He reasoned that if a proven, efficient airplane could be crashed so easily by a seasoned pilot's flying it slowly near the ground, there was something fundamentally wrong with the airplane. He canvassed the entire field of flight by heavier-than-air craft in the search for a fundamentally safe flying machine. Finally, after continuous research in theory and practice, he struck upon the idea of autogiration.

While there are many forms of autogiration, but one seemed practical to the great inventor. This was the result of extraordinarily sound and inspired engineering developed from higher mathematics. The Autogiro would have been impossible without the preliminary development of the correct theory.

On his first machine he used two 4-blade rotors. One of these was placed above the other, with the two rotating in opposite directions. He had realized that the lift on the blades while traveling with the flight path would be much greater than while going against it, and the idea of the two rotors with opposite directional rotation was calculated to cancel out the tendency to tip over. He found that the upper rotor turned much the faster, however, and the tendency to tip over was so strong that no real attempt was made to take it off the ground. This was Cierva's only attempt to use two rotors on the same machine.

His confidence was undiminished, and he set to work on the second type. It should be mentioned here that, although probably in excess of 50 or 60 Autogiros have been constructed, there have been only 6 or 8 general types, and that many models were simply slight modifications of their predecessors. The rotor of the second type employed three rigid cantilever blades. He attempted to compensate for the difference in lift between the blades while advancing and while receding by a mechanism which changed the angle of incidence of each as it revolved, giving the greater angle on the receding blade. This mechanism proved cumbersome and substantially ineffective.

On the third general type, which like the others was constructed around an airplane fuselage, he used five blades, and—it flew. The tendency to tip over was corrected with ailerons. Although it flew but a few feet, he told me that no other machine has ever given him the thrill that he experienced when this proved that an Autogiro could be flown. The machine of course had many deficiencies, chief among which was that of the strong gyroscopic force set up by the rotation of the large rigid rotor. The gyroscopic force was so strong that the controls of the machine had to be greatly modified.

Encouraged by its flight success, however, he built a model which embodied one of the main principles essential to a successful Autogiro. In this he constructed the spars of the blades with rattan,

which in itself is quite flexible. This flexibility took the place of the articulation which was the secret of success in later full-sized machines. Also, in a small model rough action would be unnoticed, since there is a very great difference between observing the performance of a model, and actually being in a machine yourself. This model flew remarkably well and encouraged him to proceed with further experiments.

It was the next machine, employing hinged joints at the attachment of the blades to the rotor hub, which proved really successful. The construction permitted the blades to flap upward and downward during rotation, so that each vane automatically took the correct effective angle of incidence at all times. For the first time, the problem of gyroscopic force, which is a very powerful influence to work against, was nullified.

Besides the immediate and great improvement in the performance of the rotor, this articulation solved a number of other besetting problems. It made autogiration possible at angles of attack where otherwise the rotation of the rotor would discontinue. In wind tunnel tests which Cierva conducted in Spain it was found that the rotor would continue to turn at every angle. This however would not be so if the blades were rigidly attached to the rotor hub.

Secondary articulation, permitting variation of the position of the blades with regard to one another along the circle which they describe, was another important step. This gave smooth action to the rotor, which before was rough. Further success came with the addition of the fixed wing, which improves efficiency in the present state of the art of the Autogiro. Before that time, Cierva had utilized ailerons on outriggers, as it had been found necessary to have some type of lateral control, although he had flown the machines with neither fixed wings nor ailerons.

Another improvement in efficiency came with the use of the geared motor. The gears in this case refer only to reduction of propeller speed since the rotor depends entirely on the action of the air during flight. A large slow turning propeller gives much greater efficiency at slow forward speeds than a smaller one turning at engine speed. The geared propeller therefore increases greatly the efficiency of the Autogiro since its best angle of climb is at a much slower forward speed than the airplane.

A step toward making the Autogiro practical is the self-starting tail invented during the past year by Cierva. This is a boxlike biplane structure by which the slipstream can be diverted upward while the machine is at rest on the ground, thus bringing the rotor to the necessary speed for take-off. Before the introduction of this feature, it had been necessary to taxi slowly for some time about the field until this rotational speed was attained.

The Autogiro presents certain new problems with the undercarriage because of its ability to land vertically. Although the vertical speed of descent in late models has been as low as 12 feet per second, the condition of landing straight down requires longer travel of the undercarriage with more shock absorption than in the airplane. A satisfactory arrangement is an oleo-pneumatic strut of very long travel combined with the Goodyear air wheel.

The stability of any flying machine is a matter of importance. At slow speeds and particularly during vertical descent the Autogiro is inherently and perfectly stable. This is because the center of gravity is well below the rotor. The center of gravity is also slightly ahead of the center of support. This provides longitudinal control during vertical descent and gives the machine a marked tendency to glide forward when the power is cut-off. This insures directional control and stability. Very slight forward speed is required for lateral control and in vertical descent stability is so great that no control is necessary even in rough weather. In fast forward speed control and stability are similar to the airplane.

In point of performance, the Autogiro offers some distinctly novel experiences to the pilot accustomed to fixed-wing craft. There is something fairly exciting about doing things which he has been instructed to avoid at peril of accident. Such, for instance, as stopping in the air, descending vertically, or even flying backward.

When stopping or descending vertically the sensation, for an airplane pilot, is uncanny to say the least. He has been taught since his earliest flying days not to lose his flying speed, but in the Autogiro this results in nothing more than slow vertical descent. And then if there is some wind and the machine is facing against it, the pilot will have the outrageous sensation of flying backwards in relation to the earth.

Slow speed flying at low altitude is a most pleasant diversion, but it is a sport attended in the airplane with great danger. In the Autogiro, on the other hand, one can fly low and slowly at will, observing at leisure the interesting features of the country. On account of the slow speed he is able to turn to one side or the other very quickly to avoid objects looming in his path; so in thick weather he can grope his way along at lower altitude than the airplane and also, on account of his slow speed, has time to see obstacles before hitting them. If the engine stops he can get down into very small spaces.

Improvement in the Autogiro must be in the nature of evolution, much as it came about in the airplane. To take a good example, our first Mailwing plane, built about three years ago, had a high speed of around 125 miles per hour with 225 horsepower. Constant refinement has increased this to 145 miles per hour. With N. A. C. A. cowl

ing this has been further increased to 160 miles per hour, yet with the same horsepower. We expect the Autogiro we have just finished to do about 120 miles per hour with the 225 horsepower, only 5 miles less than the first Mailwing, and if we compare this machine with the first Mailwing it will be readily apparent that there is much more opportunity for reducing drag in the Autogiro than in the case of the early Mailwing.

The Autogiro is much more susceptible and sensitive to improvement than is the airplane, and responds in greater degree. For instance, when we recently completed one of the first American machines, its initial flight test showed a high speed of 87 miles per hour. When the pilot landed and reported the disappointing 87 miles-per-hour speed, there were long faces to be seen everywhere.

Senor Cierva held his peace, but when he went to work on his figures that day he checked up everything and told me that 87 miles per hour was correct because of the detail arrangements; and that we would make a few changes in the machine and it would do 105. After these changes were made the next day, the machine did 105, much, I believe, to the surprise of the pilots and aeronautical experts who were present. Later, with other modifications, it definitely is expected to show around 120.

The Autogiro has many more parameters than the airplane. In their sum total and in their relationships to each other and to other combinations, they present an almost infinite variety of viewpoints, by means of which, through evolution and selection, engineers can improve the Autogiro. For instance, in the airplane we have wing area. In the Autogiro we have blade area, disk area, fixed wing area, and the relation of the various areas. In the airplane we have aspect ratio, or the relation of wing span to chord. In the Autogiro we have solidity, or the relation of blade area to disk area. In the airplane we have the wing curve, while in the Autogiro we have the curve of the fixed wing, curve of the rotor blades, and its constantly changing effective curve, caused by its differing attack as it rotates. In the airplane, we have angle of incidence. In the Autogiro, we have the speed with which the air strikes the rotor blades, which is constantly changing on account of the relation between forward and rotational speed. Then, of course, there is the all-important matter of good proportion of the above items. Small improvements to parasitic drag, power loading, and disk loading result in relatively large advances in performances.

If an airplane, by streamlining or refining some of its parts, increases it speed, say, 10 miles per hour, the same degree of refining will increase the Autogiro's speed about 15 miles per hour.

Finally, we are very fortunate in that, unlike the airplane, improvement to one phase of the Autogiro's performance helps the

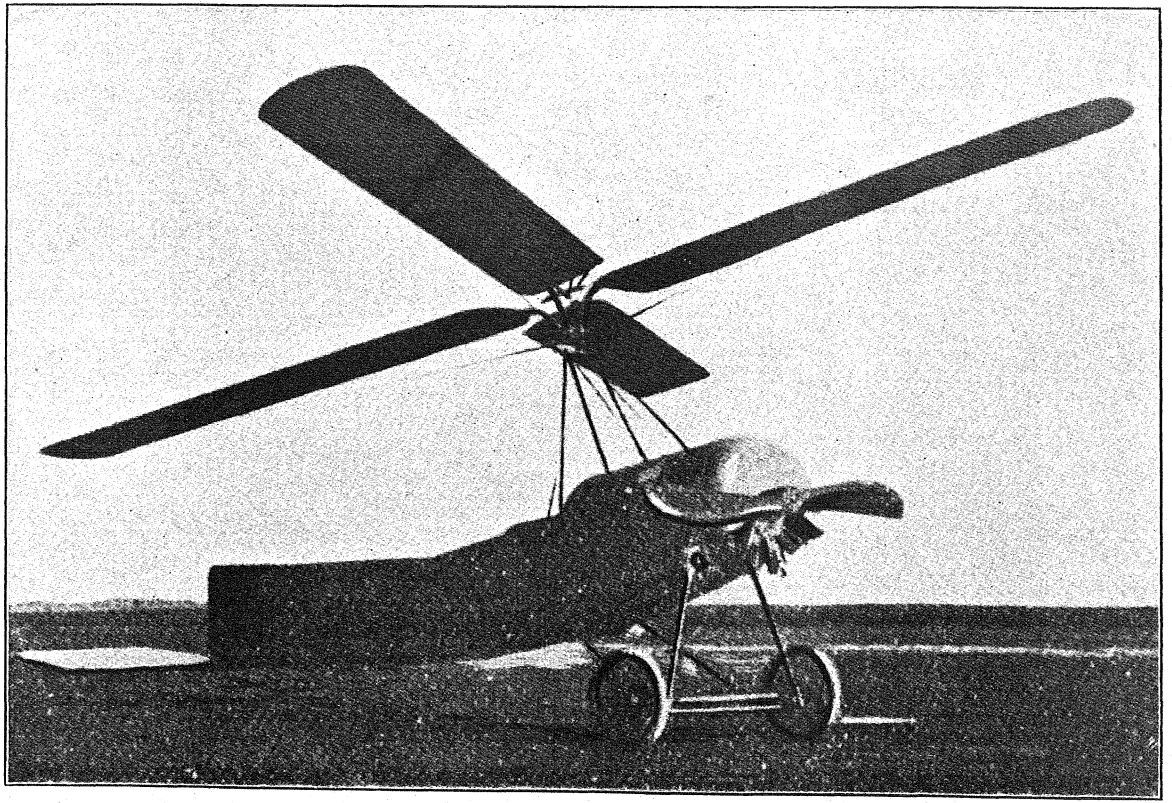
other phases. For instance, modifying the rotor for higher forward speed may be so handled as to decrease rate of vertical descent.

Without the theory worked out and developed by Cierva, all this would be impossible. Recently he has put this theory into written form for the use of engineers. He has also developed a series of graphs with accompanying explanation which will enable the engineer to calculate performance and design Autogiros of various sizes and types. This theoretical work alone would in itself be a monumental achievement for many a lesser engineer.

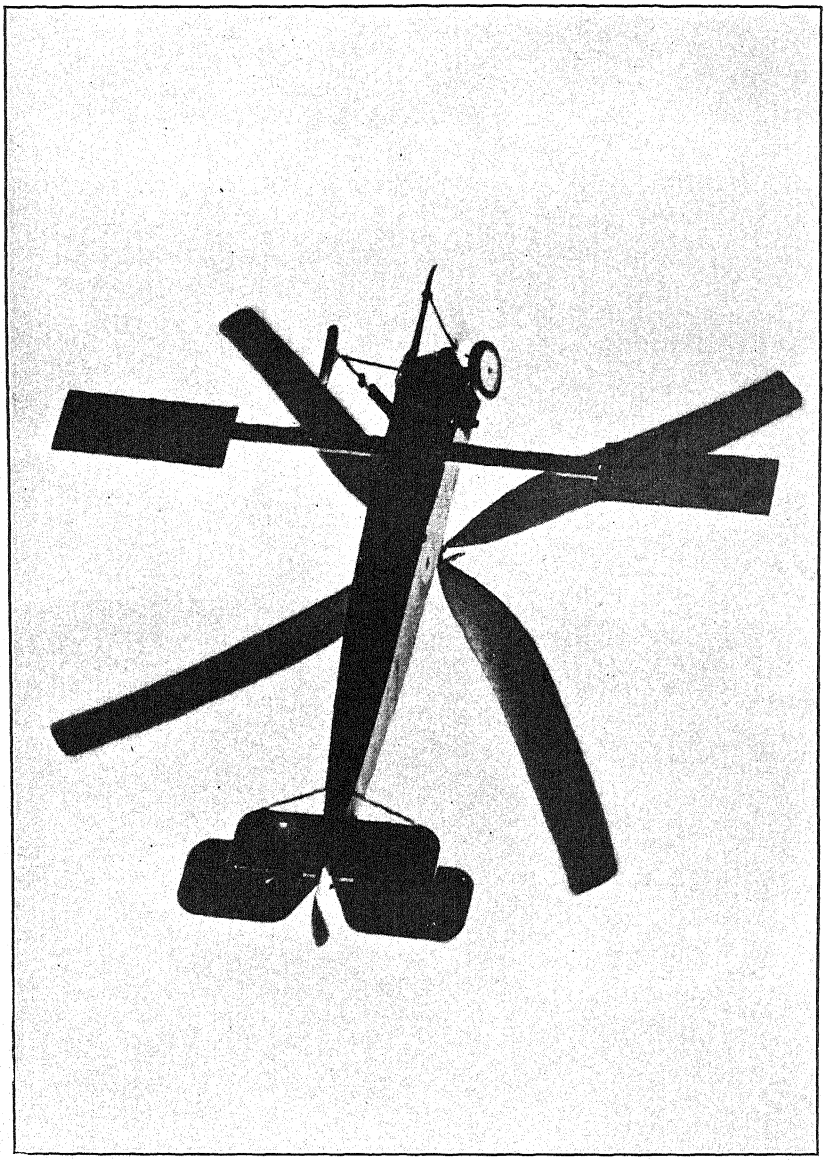
So far, as I have said, the Autogiro is the work of one man only. Think what the Autogiro will be when the same effort is put on it that has been applied to the airplane. Also, the engineers now concentrating upon the Autogiro have many more factors with which to deal than those who took the airplane in hand, and they have extensive knowledge of aerodynamics to work with, gained from wind-tunnel tests and airplane experience.

In conclusion, I may say that the Autogiro is now a practical machine, and within a reasonable time many will be produced commercially. The Autogiro is free from many of the inherent limitations of the fixed-wing aircraft, and while its performance is even now superior to the airplane in many respects, all considerations of performance are subordinated to the one feature which it affords in large measure; that feature is safety.





EARLIEST PRACTICAL AUTOGIRO, 1923, EMBODYING ARTICULATED ROTOR. FLOWN AT FIRST WITHOUT FIXED WINGS OR AILERONS



THE "DEVIL'S DARNING NEEDLE," 1925



ENGLISH AVRO AUTOGIRO (WOLSELEY VIPER ENGINE), 1927




ENGLISH AVRO AUTOGIRO (LYNX MOTOR) CROSSING ENGLISH CHANNEL, 1928



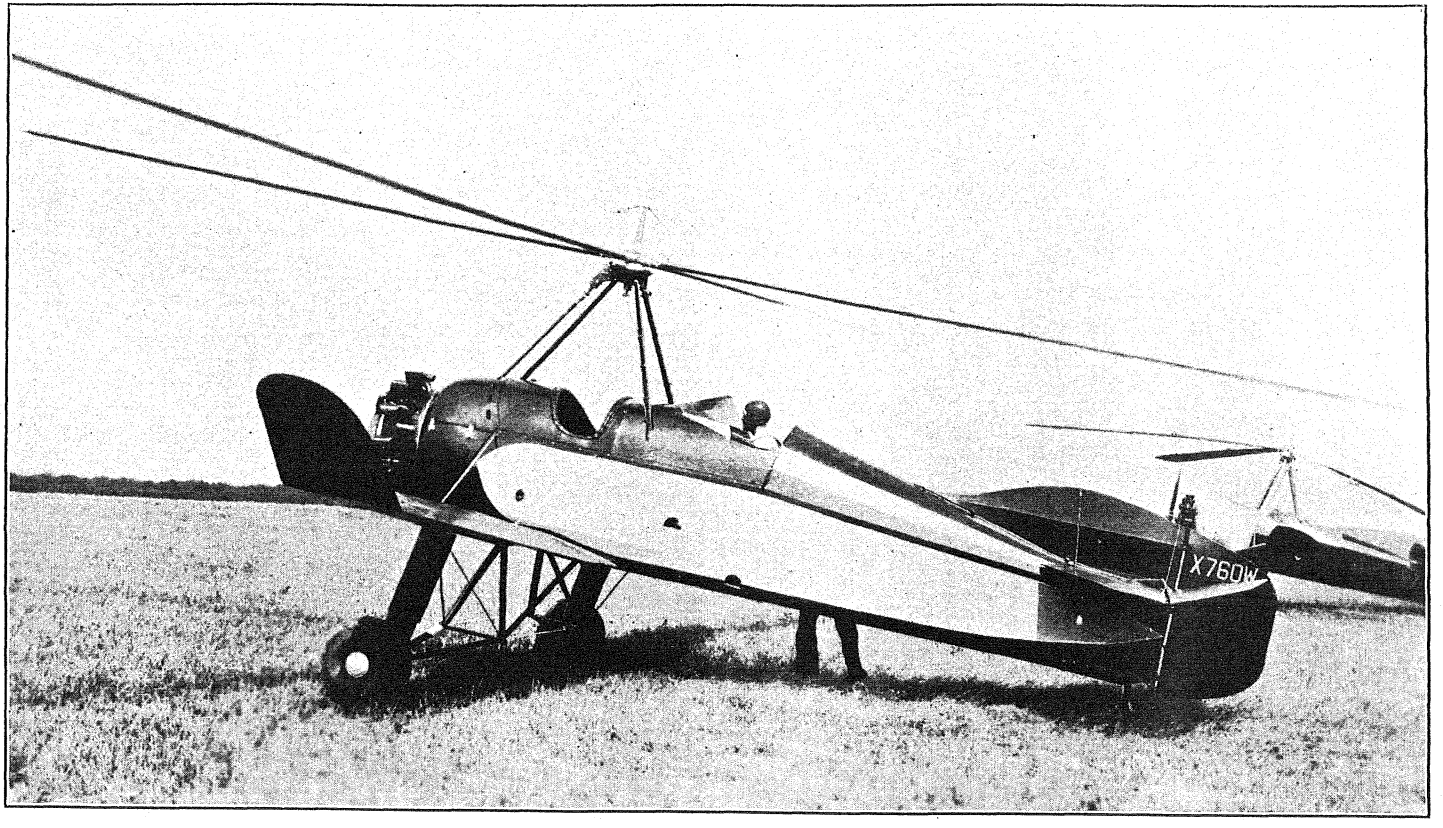
THE FIRST AUTOGIRO IN AMERICA, BROUGHT TO PHILADELPHIA LATE IN 1928 BY HAROLD F. PITCAIRN. WRIGHT WHIRLWIND (J-5) MOTOR, AVRO FUSELAGE



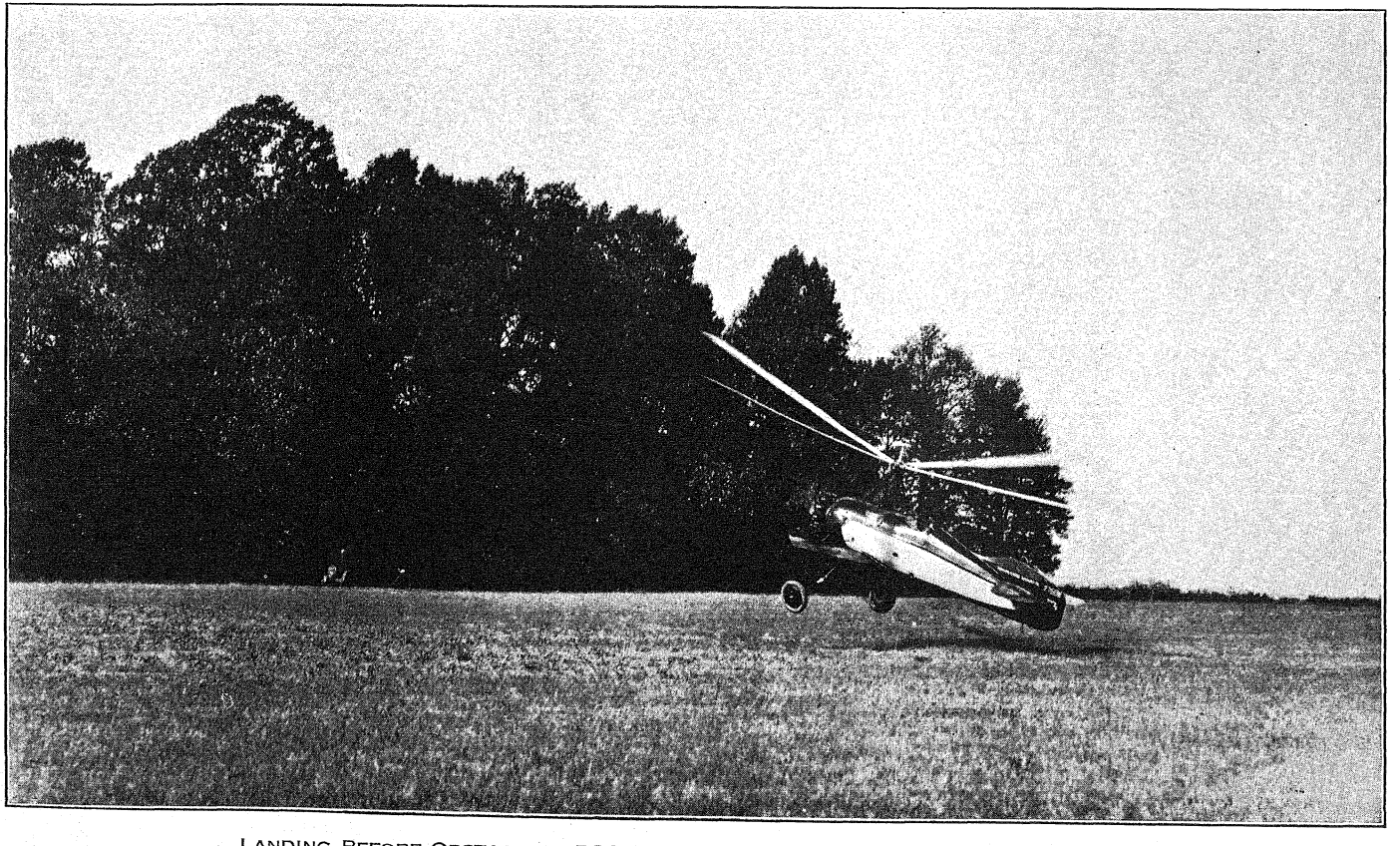

AMERICAN EXPERIMENTAL 2-PLACE AUTOGIRO (WARNER-SCARAB)




ENGLISH STANDARD C19 MARK III 2-PLACE AUTOGIRO (ARMSTRONG SIDDELEY GENET MAJOR) 1923




PITCAIRN PCA–2 3-PLACE AUTOGIRO (WRIGHT J/61225 H. P.)



LANDING BEFORE OBSTACLES. PCA-2, 1930, AT PITCAIRN FIELD, WILLOW GROVE, PA.

# TEN YEARS' GLIDING AND SOARING IN GERMANY[1]

By Prof. Dr. Walter Georgii
*Darmstadt, Germany*

[With 16 plates]

We are looking back on 10 years of development and on an unbroken series of 10 gliding competitions held at the Wasserkuppe in the Rhoen, since 1920. The organization has not only maintained its range of activities all these years but has largely extended it, and in this way has given the best proof of its vitality and purpose. In the first decade, now completed, successes have been achieved such as few foresaw, and the cause may be sought in the spirit of close cooperation with which the sportsman strove to avail himself of the flying possibilities opened up by the scientist.

This union of sport and science is in the true traditions of German gliding since its revival in 1920. At Frankfurt in that year, Oskar Ursinus directed the air-minded members of the younger generation toward gliding as a substitute for power flight of which they were perforce deprived; but he had the progress of aeronautical science at least as much at heart as the interest of the sport. He desired to direct aeronautical investigation along a new path, and to free it from the restricted view that progress was bound up with power flight. Were it possible to develop gliders carrying appreciable loads, they would serve as prototypes for light airplanes, without losing sight of more general sporting possibilities. The evolution of the light sporting airplane from the glider was his technical objective. His sporting aim was to offer keen youngsters a chance of flying at no great financial outlay by giving their time freely to constructing gliders. In the course of their purely sporting activities they would develop a sound team spirit and would find a stimulus to technical and scientific work.

On his initiative the first gliding competition at the Wasserkuppe in the Rhoen was held in August, 1920. In spite of initial difficulties a new gliding record of 2 minutes 22 seconds, and of 1,830 meters, was made by W. Klemperer, whose design (pl. 1, fig. 1) first

[1] Lecture delivered before the Royal Aeronautical Society, London, on Feb. 19, 1930. Reprinted by permission of the society.

settled the type of construction suitable for gliders. It was a cantilever low-wing monoplane, in which great care was given to keep down drag with its adverse effect on performance.

In the following year the same principle of keeping down body drag was more fully applied by G. Madelung to his glider *Vampyr*, the design of which has had a lasting influence. The Vampyr type prevails at the present time, and this is a measure of Madelung's contribution to glider design.

Since gliding flight depends on the use of slowly rising currents in the air, a practicable glider is chiefly characterized by a small vertical component of velocity, or sinking speed. A small rate of descent may be obtained either by reducing the sum of the resistances or by reducing the wing loading. These two methods have been applied, and lead to two special types of glider, both of which find application for special purposes. A large span and good aspect ratio are favorable to a small (induced) drag, and further reduction of drag is gained by a closed body, cantilever contruction (no external bracing) and by dropping the starting carriage.

From the *Vampyr*, the prototype of German high-performance gliders, onwards, all these methods of reducing drag have been carefully studied and carried out, so that further fundamental improvements are scarcely to be expected. The following photographs show the best-known German high-performance gliders from the *Vampyr* of 1921 to the *Wien* of 1929:

*Vampyr*, Academical Flying Club of Hanover, 1921 (pl. 1, fig. 2); *Consul*, Academical Flying Club of Darmstadt, 1923 (pl. 2, fig. 2); *München*, Academical Flying Club of Munich, 1928 (pl. 3, fig. 1); *Wien*, R. Kronfeld. Built by A. Lippisch, 1929 (pl. 3, fig. 2.).

On the *Wien*, Kronfeld carried out his great duration flights, covering distances up to 150 km.

In designing for low head drag the structural weight is increased to a restricted degree, and the structural methods, illustrated above, produce medium heavy gliders with a margin of strength for high performance and for flying in gusty weather. The additional weight gives the greater air speed required for progress against strong winds and for passing rapidly through unfavorable belts of down wind. The glider of low drag and considerable structural weight is the best all round for long cross-country glides by virtue of its slow descent and high air speed.

Another method of reducing the sinking speed, by reducing the wing loading, is widely applied to glider design but quite unsuitable for high performance. It produces a very special type with low air speed, poor gliding angle, light structural weight, and simple form.

The *Djalvar Anamma* ("Devil take it") is of this type and its main characteristics are: Braced monoplane wings, simple girder, tail hook, and boat-shaped cockpit below the wings. Plate 3, Figure 3, shows a standard glider of this type.

It has a good duration performance in light winds but a restricted range on account of its slow air speed. In the school type the aerodynamical qualities are sacrificed to more robust construction, simplified for ease of repair; the cockpit is not covered so that the pilot may fall clear in a smash, and restricted gliding and soaring powers are desirable for training purposes. The best known of this derived type is the *Zoegling*, shown in Plate 4, Figure 1.

Once the principles of successful soaring were recognized, results soon followed. In 1922, Hentzen and Martens, both students, carried out the first soaring flights, lasting over an hour, on the *Vampyr*. Hentzen's record flight of 3 hours 10 minutes, attaining an altitude of 350 m., made the activities at the Wasserkuppe world famous.

It elucidated the problem of soaring flight by using the energy in the air's motion. In accordance with the laws of motion soaring is possible in an ascending current of air, and in a horizontal air current of variable velocity.

When the rate of ascent of the air current equals or exceeds the rate of descent of the glider, "static soaring" is possible. When the horizontal wind is variable, the pilot gains height as the velocity increases and loses height as the velocity decreases. As the air forces are proportional to the square of the air speed, it is possible in principle to obtain a net gain. If the net rate of gain equals or exceeds the sinking speed, this "dynamic flight" becomes possible. It is quite probable that some dynamic gain was obtained in the earlier flights, but not by any systematic use of the wind fluctuations.

The extensive efforts made from 1921 to 1923 to connect pulsating dynamical effects with the performance of man-carrying gliders did more harm than good to the development and reputation of soaring, the possibilities of which, apart from any such effects, have been fully shown by the subsequent years.

To revert to static soaring, local rising currents are produced by every irregularity of the earth's surface—knolls, dunes, woods, the waves of the sea—and may be utilized for soaring flight. The following photographs show well-known soaring grounds:

The Wasserkuppe in the Rhoen (pl. 5, figs. 1, 2); the French soaring grounds at Vauville (pl. 6, fig. 1); and the soaring grounds at Rossitten on the Kurisch Lagoon (at the mouth of the Memel in East Prussia) (pl. 4, fig. 2).

The following table shows a number of duration records:

| Year | Wasserkuppe | | Year | Rossitten | |
|---|---|---|---|---|---|
| | Pilot | Duration | | Pilot | Duration |
| | | H. m. | | | H. m. |
| 1922 | Hentzen | 3 10 | 1924 | Schulz | 8 24 |
| 1928 | Kronfeld | 7 24 | 1925 | do | 14 7 |
| 1929 | Neininger | 8 24 | 1929 | Dinort | 14 43 |

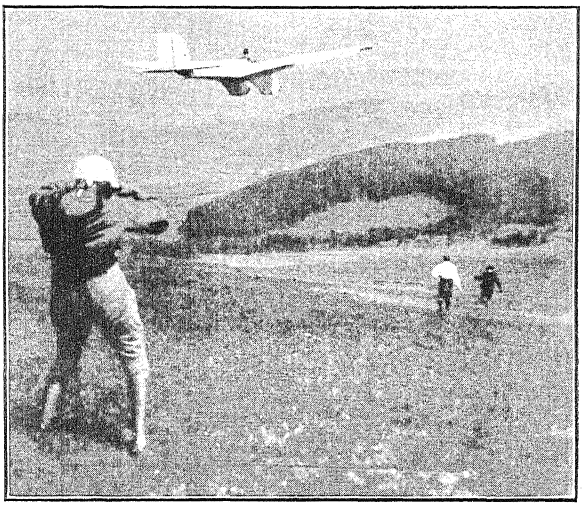
It is seen that the records at the Wasserkuppe have dropped far behind those at Rossitten. Such flights are a useful stimulus to the sport but do not much help further developments of soaring. For this reason cross-country flights have been preferred at the Wasserkuppe as eminently serviceable for research work, and by this means alone new regions of favorable rising winds have been delimited, and the practice of soaring has been made less dependent on time and place. The performance has been steadily improved and a high aeronautical and scientific standard of instruction in the methods of soaring has been attained. The following table shows the progress made since 1922:

*Cross-Country Soaring Flights*

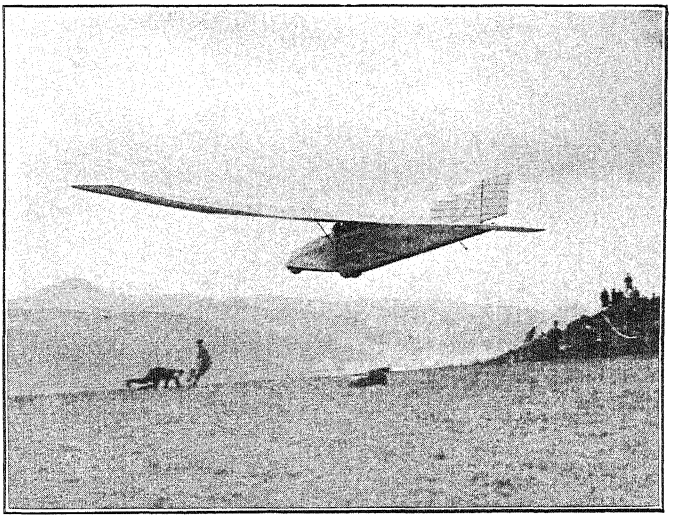
| Year | Pilot | Distance in kilometers | District |
|---|---|---|---|
| 1922 | Martens | 9.5 | Wasserkuppe. |
| 1923 | Botsch | 19 | Do. |
| 1925 | Nehring | 21 | Do. |
| 1927 | do | 52 | Do. |
| 1928 | Schulz | 62 | Rossitten. |
| 1929 | Nehring | 72.3 | Odenwald. |
| 1929 | Kronfeld | 100 | Teutoburger Wald. |

The technique of cross-country soaring flights is best shown by plotting the course on a counter map, with barogram readings of the heights attained, and other information supplied by the pilot. Plates 8 and 7 show the masterly flights of Nehring and Hirth, from the starting point round a fixed mark and back. Soaring flight by Nehring round the Heidelstein on the *Darmstadt*, August, 1927, is shown in Plate 8, Figure 1; soaring flight by Hirth round the Schweinsberg on the *Lore*, July, 1929, is shown in Plate 7, Figure 1.

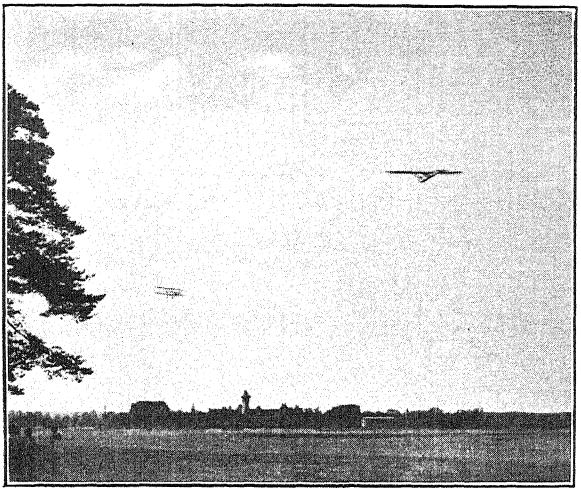
In the flight round the Heidelstein, Nehring first soared over the south slope of the Wasserkuppe until he had gained 150 m. height above the starting point. He then flew parallel to the ridge and at right angles to the prevailing wind to Münzkopf, where he used the strong upcurrent to reach his maximum height at 260 m., which was sufficient to reach the Heidelstein and return to the starting point.



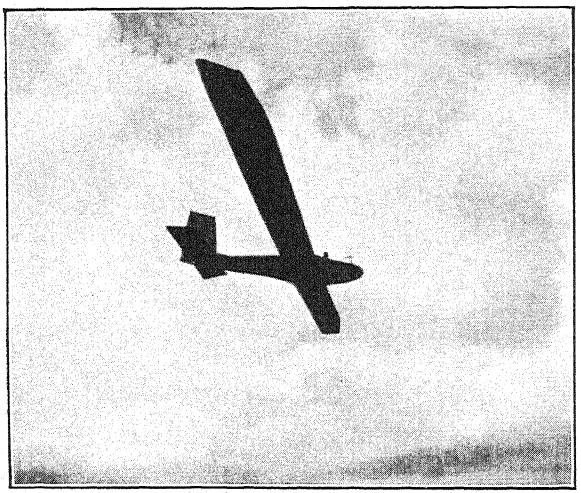
1. KLEMPERER'S SAILING AIRCRAFT, 1920



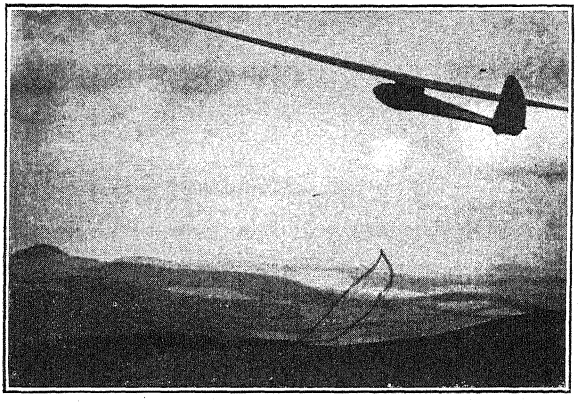
2. "VAMPYR" GLIDING, 1921



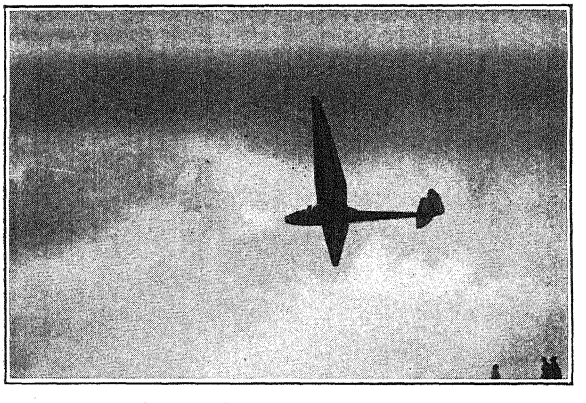
1. TOWED FLIGHT IN DARMSTADT



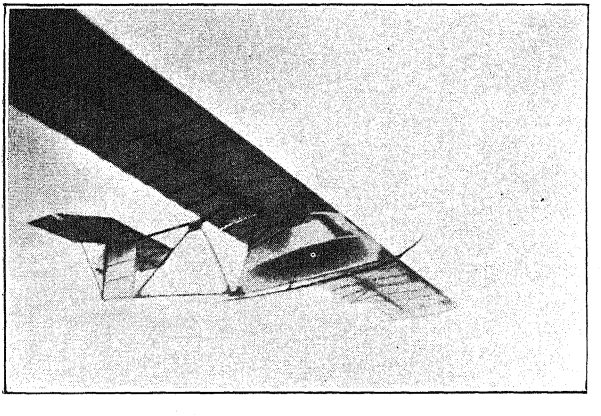
2. SAILING AIRCRAFT "CONSUL" OF THE DARMSTADT ACADEMIC FLYING GROUP, 1923



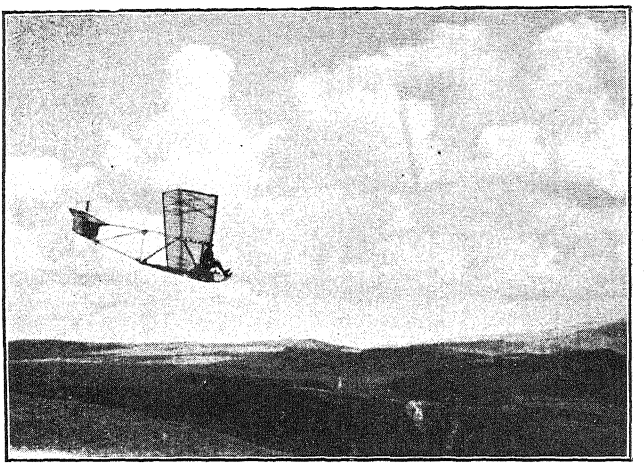
1. SAILING AIRCRAFT "MÜNCHEN" OF THE MUNICH UNIVERSITY FLYING GROUP, 1928



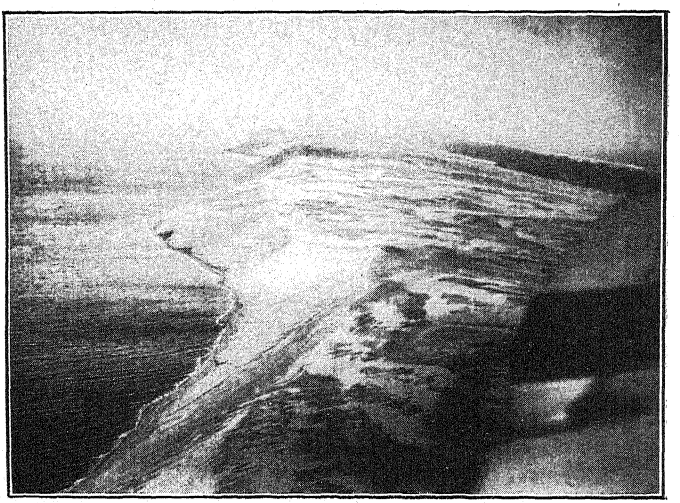
2. SAILING AIRCRAFT "WIEN," R. KRONFELD'S AIRCRAFT, CONSTRUCTED BY A. LIPPISCH, 1929



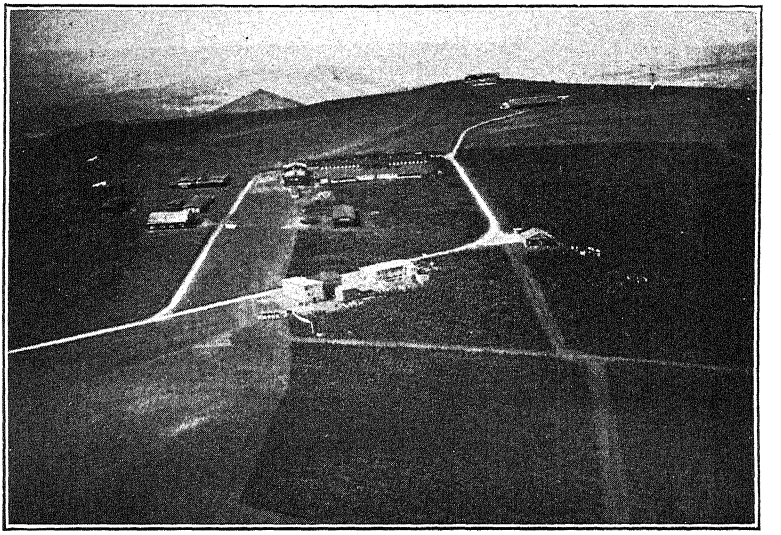
3. DJALVAR ANAMMA



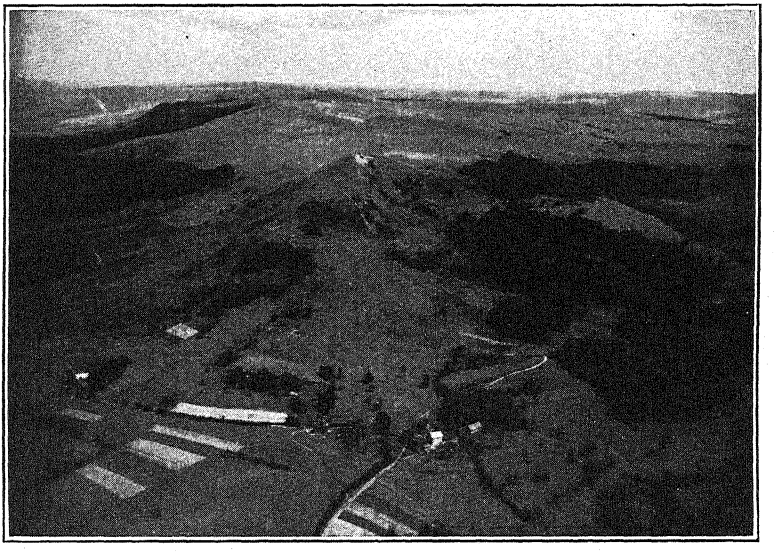
1. INSTRUCTIONAL GLIDER "ZOEGLING" OF THE RHOEN-ROSSITTEN CO., 1926



2. GLIDING GROUND AT ROSSITTEN FROM THE NEHRUNG



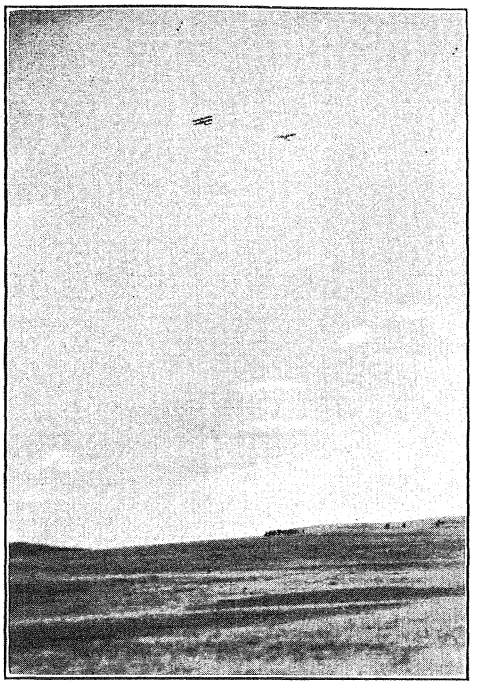
1. SAILING FLIGHT GROUNDS AND FLYING STATION ON THE WASSERKUPPE IN THE RHOEN



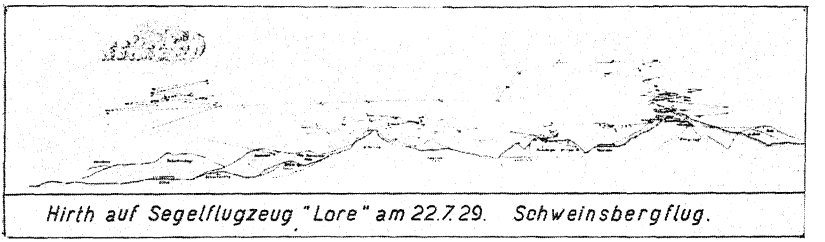
2. WESTERN DECLIVITY OF THE WASSERKUPPE, RHOEN. MAIN SAILING FLIGHT DECLIVITY



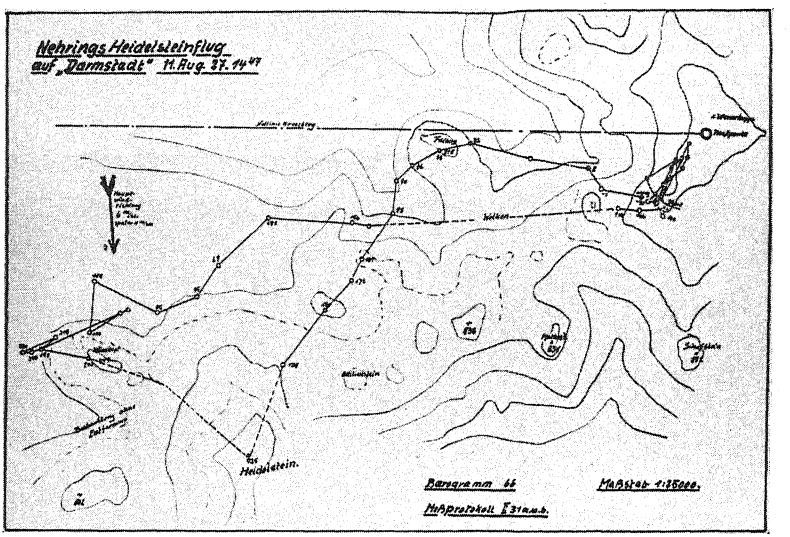

1. FRENCH SAILING FLIGHT GROUNDS NEAR VAUVILLE



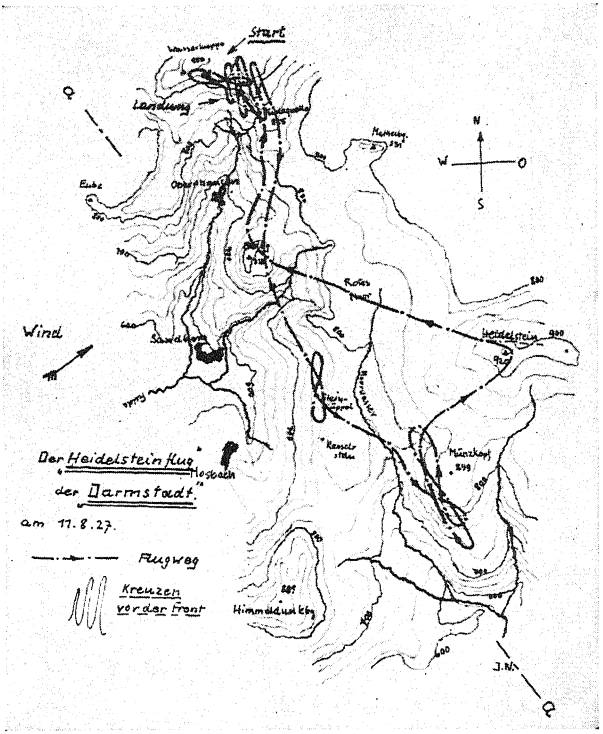
2. TOWED FLIGHT ON THE WASSERKUPPE



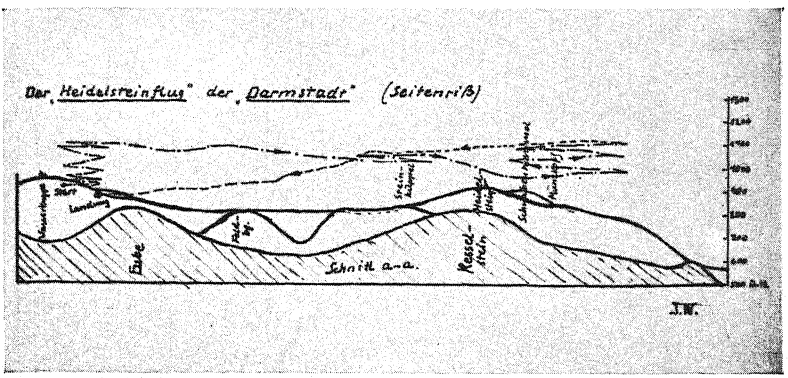

1. SCHWEINSBERG FLIGHT BY HIRTH ON THE SAILING AIRCRAFT "LORE," JULY, 1929



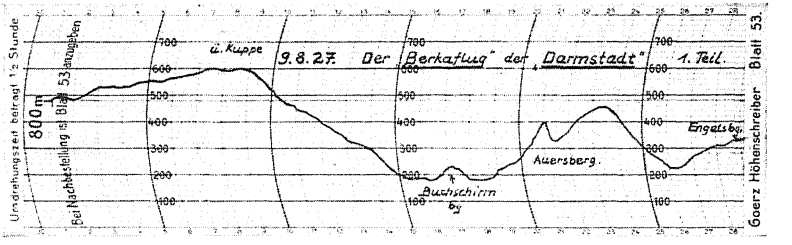

2. HEIDELSTEIN FLIGHT BY NEHRING ON THE SAILING AIRCRAFT "DARMSTADT," AUGUST, 1927. COURSE OF FLIGHT ACCORDING TO TRIGONOMETRICAL MEASUREMENT



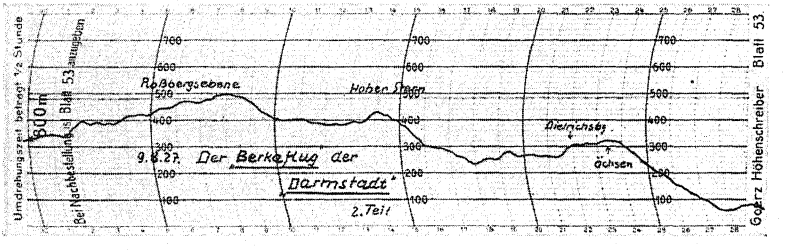

1. HEIDELSTEIN FLIGHT BY NEHRING ON THE SAILING AIRCRAFT "DARMSTADT," AUGUST, 1927. PLAN OF THE COURSE OF FLIGHT



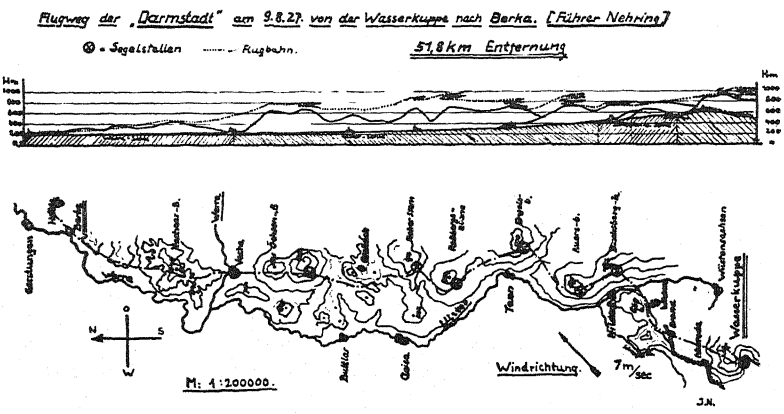

2. HEIDELSTEIN FLIGHT BY NEHRING ON THE SAILING AIRCRAFT "DARMSTADT," AUGUST, 1927



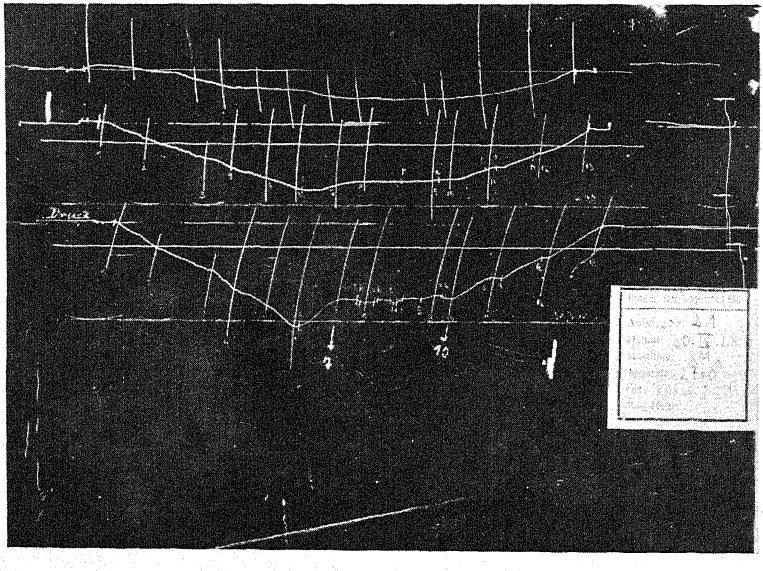

1. BAROGRAM OF THE FLIGHT BY NEHRING TO BERKA, AUGUST, 1927



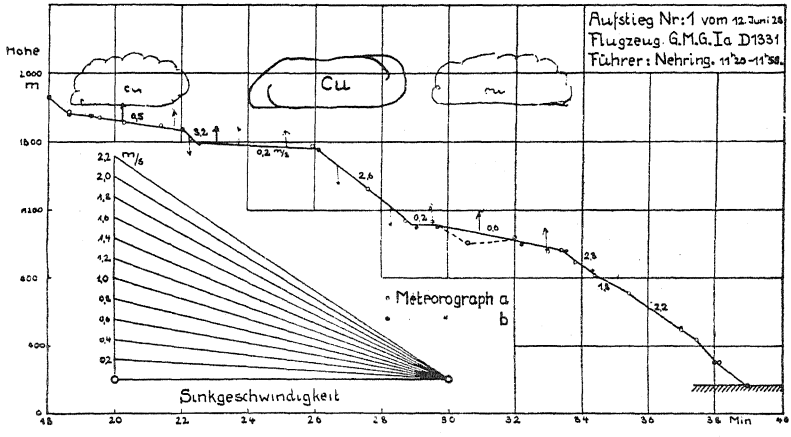

2. BAROGRAM OF THE FLIGHT BY NEHRING TO BERKA, AUGUST, 1927



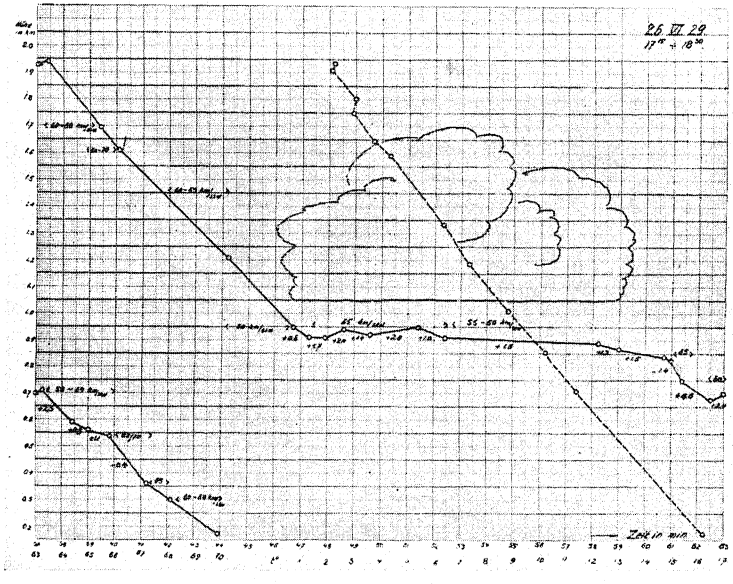

1. VERTICAL SECTION AND PLAN OF THE COURSE OF THE FLIGHT BY NEHRING TO BERKA. DISTANCE FLOWN 53 KILOMETERS, AUGUST, 1927



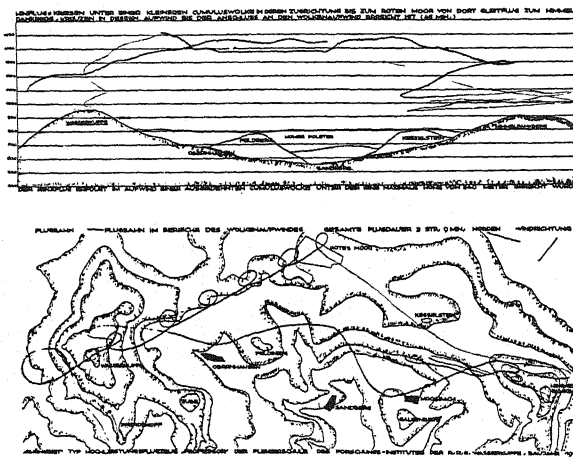
2. METEOROGRAM OF THE SURVEY FLIGHT OF APRIL 30, 1928



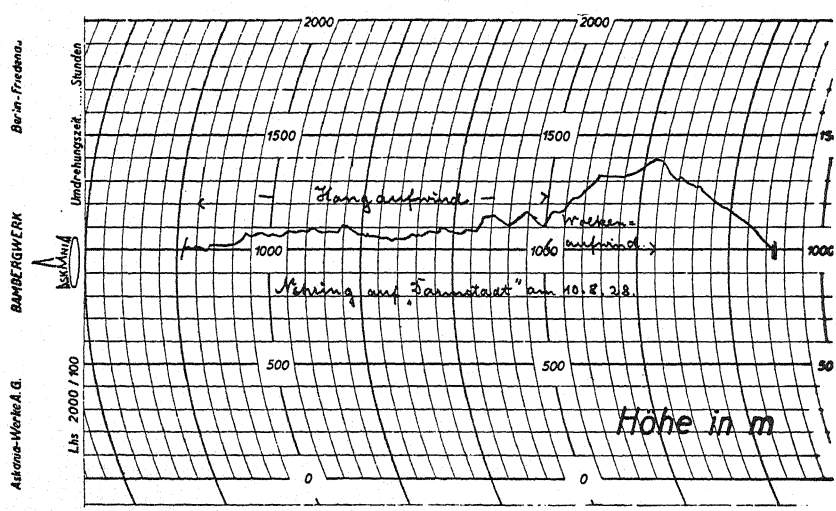

1. TESTING OF A WIND-BORNE SURVEY FLIGHT OF JULY 12, 1928



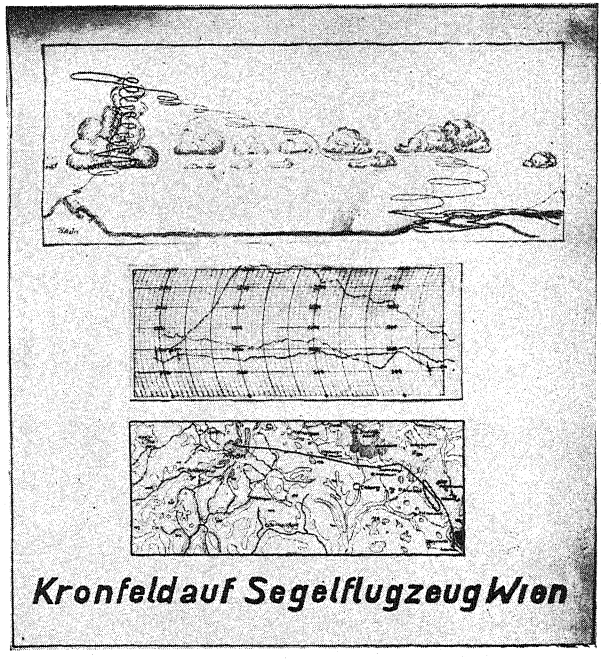

2. TESTING OF A WIND-BORNE SURVEY FLIGHT IN THE FACE OF A SQUALL ON JUNE 26, 1929



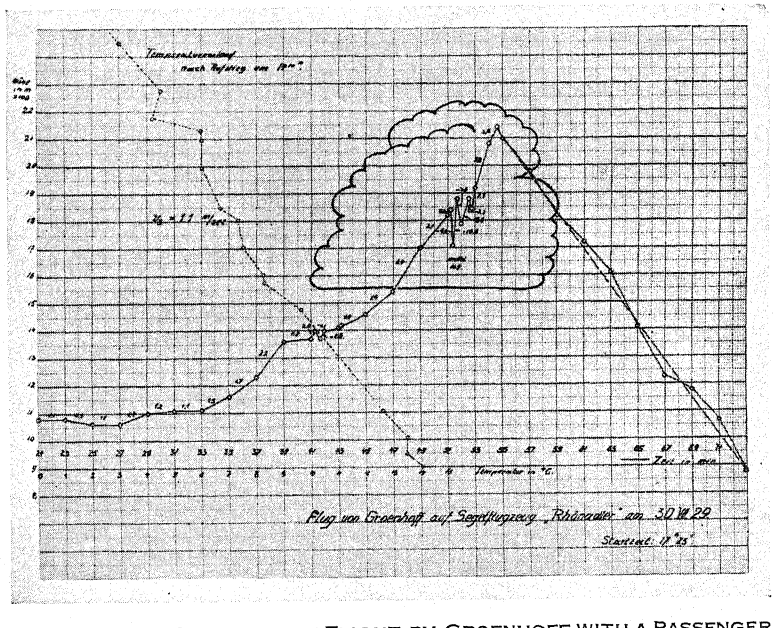
1. THE HIMMELDANKBERG FLIGHT BY R. KRONFELD



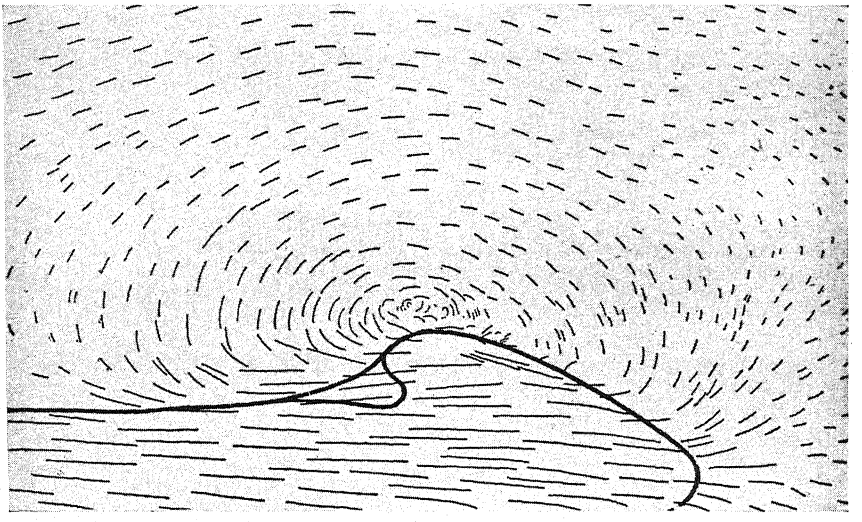

2. SAILING FLIGHT BAROGRAM OF THE AIRPLANE "DARMSTADT" OF AUGUST 10, 1928




1. THE 150-KILOMETER FLIGHT BY KRONFELD FROM THE WASSERKUPPE TO BAYREUTH, AUGUST, 1929



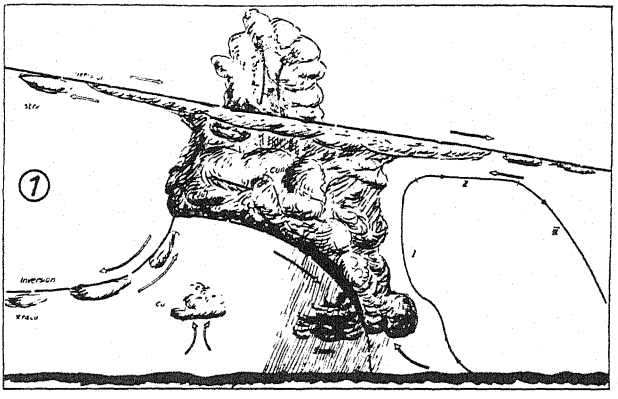

2. BAROGRAPH CURVE OF THE FLIGHT BY GROENHOFF WITH A PASSENGER ON JULY 30, 1929

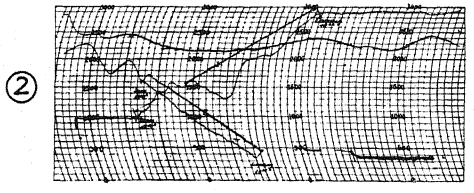


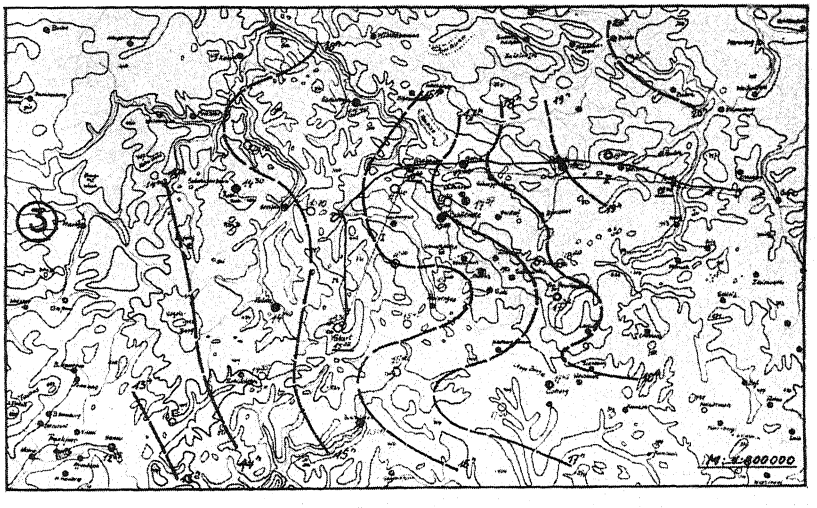
1. MOVEMENT OF THE AIR ON THE ENTRANCE OF COLD MASSES OF AIR INTO WARMER MASSES, ACCORDING TO W. SCHMIDT



2. THE TAILLESS AIRPLANE "STORCH" AS A SAILING AIRCRAFT

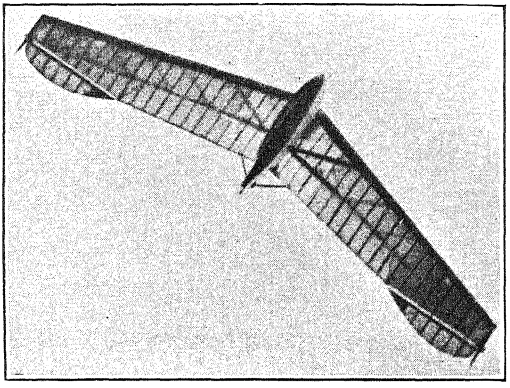


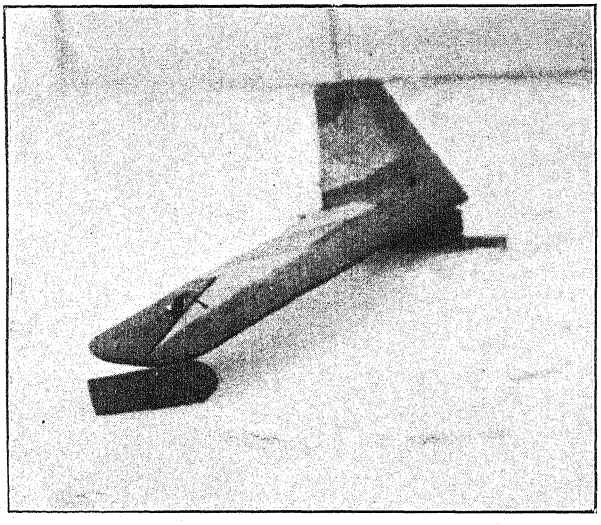




ROUTE SAILING FLIGHT BY KRONFELD OF 143 KILOMETERS IN THE FACE OF A STORM

1, Representation of the face of the storm and the path of flight before it; 2, barogram of the flight; 3, movement of the face of the storm and horizontal path of flight.



1. TAILLESS AIRPLANE "STORCH" WITH 8-HORSE-POWER D. K. W. ENGINE



2. TAILLESS AIRPLANE "STORCH" AS A MODEL

Hirth's flight was more difficult and more instructive. He started from the west slope of the Wasserkuppe, and maintained himself there until he had gained 400 m. in height, and then carried out his cross-country flight to the immediate neighborhood of the Schweinsberg without serious difficulty. On the return flight he found that he had lost height badly and was 200 m. below the starting point. He was twice forced to turn back and soar over valleys with upwinds in order to regain sufficient height to regain the western slope, over which he cruised until he was high enough to land on the plateau of the Wasserkuppe at the prescribed point.

In this admirable exhibition of the methods of cross-country work, it is seen that the pilot leaves the original region and seeks new areas of rising wind, leaving nothing to chance, but laying his course beforehand, according to the wind prevailing and to the lay of the land. It is characteristic of such flights that the best course is not in general the shortest distance, but may involve long detours in reaching upwind areas, and lengthy soaring over a particular point in gaining sufficient height. Briefly, the pilot must fly on sound topographical and meteorological information, if he is to reach his goal. Cross-country flights will be achieved over wide regions by flying from slope to slope, from hill to hill, and finally, from range to range. The satisfaction of skillfully adapting soaring flight to the configuration of wind currents and landscape is enhanced, if need be, by the sporting excitement and by the real value to flying.

Nehring's 1927 flight is another instructive example of cross-country work in which a whole range was traversed by passing from hill to hill. There was no straightforward continuous region of upwinds available. Local areas of rising wind had to be sought out on slopes facing the general direction of the wind, and wide belts of downwind lying between them had to be crossed. The masterly fashion in which Nehring carried out these successive stages is shown on Plate 8.

A barogram of Nehring's 53 km. flight to Berka, August, 1927, is shown in Plate 9, Figures 1, 2, and a plan and height contour of the same flight in Plate 10, Figure 1.

The ups and downs of the barogram correspond to the up- and downwind regions which were met. The plan of the course shows very well the flying tactics adopted in circling over hills which produced rising winds, long enough to gain extra height for the next stage of the flight.

Kronfeld's 100 km. flight in spring, 1929, over the Teutoburgerwald was achieved by these same tactics, and supports the view that a sound knowledge of the flow of the wind round hill ranges, hills, knolls, and dunes enables a soaring pilot, competent in his art, to achieve remarkable cross-country performances, over hill and dale.

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We can not remain content to restrict soaring to hilly country but must strive to bring within its scope the regions of the air above flat lands. The sailing flight of birds, indeed, shows that upwinds exist over plains, and are probably adaptable to soaring man flight.

Research on soaring was initiated just at the beginning of the serious crisis of 1924 and 1925. Soaring gliders had not been involved in the restrictions imposed on power aircraft, but were adversely affected by the revival of interest in the sporting possibilities left open to light airplanes, when the worst restrictions were removed.

After the record duration soaring flights of 1922, England, France, Italy, and Russia had held soaring competitions, but interest had soon passed back to the light airplane. Even in Germany soaring came to be regarded as a mere makeshift for power gliding. Only when this erroneous view had been disproved, and soaring shown to have its own individual scope, did the crisis pass.

The Rhoen Rossitten Gesellschaft was founded in these difficult times, with the purpose of supporting gliding schools, of holding competitions to give publicity, of improving performance, and of stimulating gliding activities generally. A special research department was established at the Wasserkuppe for advancing technical and scientific knowledge of the problems involved, and the management was placed in the hands of the writer in 1926.

The Rhoen Rossitten Gesellschaft may be regarded as the center of the gliding movement in Germany and in other countries. Teams were sent to the meetings in the Crimea at Asiago and at Vauville. Instructors were sent to the United States on the formation of the American gliding school at Cape Cod. A French educational commission has received full training, and this has stimulated the sport in France. Technical advice has been given to Hungary, Holland, and Belgium. In these ways the society has made its contribution to the common problem of soaring flight to which in turn all other nations can contribute their activities. Since 1926, having overcome the crisis of 1924–25, the practice of soaring and gliding has made vigorous and continuous progress. Glider schools have been established, and standard gliders have been distributed along with working drawings and instructions for building them. These include the Zoegling, Prüfling, and Professor types. The number of air-minded youngsters and their interest in gliding have been increased by these measures, and, above all, research has opened out new possibilities and has contradicted the prevailing belief that soaring depends entirely on the use of rising current over hill slopes.

The investigations of rising currents in the free atmosphere carried out in the last few years at Darmstadt and at the Wasserkuppe have shown that soaring under cumulus clouds and near cold fronts is practicable, both entirely new conditions.

It has long been known that cumulus clouds are associated with rising currents of air, but few measurements were available. Research was directed to the determination of these currents in the spring of 1928 from measurements of the vertical rate of a power plane gliding beneath a cumulus cloud with its airscrew stopped. Repeated glides of as long as 10 minutes without loss of height were obtained.

Plate 10, Figure 2, shows a meteorgram of experimental flight, April 30, 1928. It is seen that there was no loss of height from point 7 to point 10 of the barogram, which implies a rising current of 2 m./sec.

Plate 11, Figure 1, shows a reduction of experimental flight measurements in a rising current, July 12, 1928, and the observed descent of the airplane gliding. From this is subtracted the known sinking speed in still air, about 1.9 m./sec. The difference measures the vertical motion of the air.

From time 20 minutes to time 28 minutes there is a rising current of from 1 m./sec. to 2 m./sec., and from 28 minutes to 30 minutes of 2 m./sec. to 5 m./sec. These are high values and give excellent conditions for soaring in gliders, which have sinking speeds as low as 0.7 m./sec.

Plate 11, Figure 2, shows a reduction of rising current measurements before a line squall, June 26, 1928. A "cold front" produced a line squall of moderate intensity, and the airplane, with airscrew stopped, maintained itself without loss of height for 15 minutes. From these results it was inferred that a soaring glider starting from the Wasserkuppe could reach the region of rising currents under a cumulus cloud or the front of an approaching squall, and this was successfully accomplished.

Plate 12, Figure 2, shows a barogram of soaring flight by the *Darmstadt*, August 10, 1928. The barogram shows clearly the vigorous effect of the rising current under a cloud in comparison with that produced by a hill barrier.

The *Darmstadt* maintained itself over the west slope of the Wasserkuppe at 100 meters above the starting point. In 20 minutes, the boundary of the up-current below an approaching cloud was reached and the glider was quickly carried up to a height of 400 m.

Plate 12, Figure 1, shows a record of Kronfeld's flight at the Himmeldankberg, August, 1928. The plan of the course is shown in full line under the cloud, in dotted line outside their influence.

Kronfeld started from the western slope of the Wasserkuppe, and flew at once toward an approaching cumulus cloud, which he followed toward the east with continual gain of height, reaching finally 470 m. above the starting point. The cloud began to dissipate and the up-current became ineffective, so that Kronfeld left it and

flew with considerable loss of height to the Himmeldankberg as prearranged, and there soared for some time in the up-currents. On the approach of another cumulus cloud Kronfeld used it to gain considerable height, and then flying always from cloud to cloud he reached the Wasserkuppe at his maximum height of 540 m. above the starting point.

These details illustrate the difference between hill and cloud flying, between flying from hill to hill over a course, which must be adjusted to the contours of the ground, and flying from cloud to cloud over hill and plain, when the ground is ignored and the pilot scans the cloud formations and adjusts his course to their motion.

Plate 13, Figure 2, shows a barogram of Groenhoff's flight with a passenger on the 2-seater *Rhoenadler*, July 30, 1929.

The next flight shows the extended performance obtained by flying into the cloud instead of soaring below it. Groenhoff started from the west slope of the Wasserkuppe and soared over it for a short time, then flew under a cumulus cloud and rose through it almost to its summit, reaching a maximum height of 1,250 m. above the starting point, and covering a course of 33.3 km., both figures being records for soaring flight with a passenger.

The sinking speed of the glider in still air was 1.1 m./sec., from which the vigor of the upwinds may be inferred.

Severe vertical gusts were met with in the cloud. At 1,800 m. the glider was driven down 140 m. in a few seconds and immediately after it was carried up 170 m. Two more such gusts followed after. The reduction gives a down-current of 9 m./sec., and an up-current of 10 m./sec.

On the same day and under the same weather conditions Kronfeld made his great cross-country flight of 150 kilometers. Plate 13, Figure 1, shows Kronfeld's soaring flight from the Wasserkuppe to Bayreuth (150 km.)

Immediately after the start Kronfeld flew under a cumulus cloud and was carried up continuously to a height 2,150 m. above the starting point. The up-current given by the measurements was 5 m./sec. After leaving the cloud, height was slowly lost in passing over flat country. In two hours the Threungerwald was reached, and the flight was continued for 4 hours in the rising currents from the ridges. Finally a landing was made at the Fichtelgebirge 150 kilometers from the Wasserkuppe.

This masterly flight is a fine example of the art of soaring, and illustrates the manner of utilizing the various means available. In particular a record height in this manner was gained in the up-current of a cumulus cloud formation sufficient to cross flat and

hilly country alike, independently of the consideration of the surface.

The most important result is the ease with which great heights can be reached in the up-currents of cumulus-cloud formations. The second part of the flight gives fresh evidence of the value of the older established method of flying in the up-currents from hills.

A more recent development of cloud flying is the use of up-currents at the cold air fronts of line squalls, of which measurements with an engined aeroplane have been referred to. In this type of atmospheric disturbance masses of warm air are pushed up by the inrush of cold air along the surface of the earth. Plate 14, Figure 1, shows motion of the air caused by cold air flowing in under warm air (W. Schmidt). The lines of flow show the local direction of the wind. In front of the line squall the air rises almost vertically and offers the best soaring region.

Plate 15, Figures 1, 2, and 3, shows Kronfeld's flight in front of a line squall (143 km.), the region of up-currents before the cold front, the barogram of the flight and the time changes in the line squall along the course.

Kronfeld started at the moment when the wind was freshening, just before the passage of the line squall, and by utilizing the rising currents before the cold front rose 2,000 m. above the starting point. The middle part of the barogram shows that he then maintained steady flight.

The meteorological records determine the motion of the storm accurately, and in conjunction with the pilot's account lead to the conclusion that he flew about 2 km. in front of the squall, rising or falling slightly as he was nearer or farther. After turning away from the front the glider rapidly lost height and landed 143 km. from the Wasserkuppe after 4½ hours flight.

The knowledge gained as to the configuration of line squalls, leads to the conclusion that there is no danger if the pilot keeps some distance before the advancing front.

It appears from recent investigations at the research institute of the Rhoen-Rossitten Gesellschaft that heights of 4,000 to 4,500 m. above the starting point may well be attained, in comparison with the existing record of 2,150, and that the cross-country record of 150 km. may be increased in like proportion.

Plate 6, Figure 2, shows a flight with towed glider at the Wasserkuppe. Systematic experiments have been carried out by the society with gliders towed by power airplanes and released at a sufficient height to reach regions of up-currents and to continue independent cloud flying. Plate 2, Figure 1, shows a flight with towed glider at Darmstadt.

## THE PROSPECTS FOR SOARING FLIGHT

The performances recorded above show that flying without engine power, by using the energy of rising currents in the atmosphere, is already established. We can not, indeed, expect it to meet the requirements of air transport, but its value as a sport can not be questioned, and as such is on a high level in its demand for physical fitness, skill, quick decision, and courage, and in addition a serious study of the scientific and technical problems involved.

Especially, soaring flight has had a beneficial effect on the design of light airplanes which now give performances with low engine power which were only possible formerly with powerful engines.

The soaring glider with an auxiliary engine is unsatisfactory both as a glider and as a power airplane, and this line of development has been given up in Germany except for special research work.

The research institute of the society has recently established a new and important system of aerodynamical tests of new aircraft types. In the first place free flights by large models of three to four meters span are carried out at small cost. When all that can be learned from the models has been recorded, gliders of similar aerodynamical form are built and tested by a pilot in different flying attitudes. Finally, an engine is fitted and ordinary flying tests are carried out. In this way the successive steps in the development of a new type are carried, with minimum of cost and danger, to a point where the design of the full-sized airplane offers no serious uncertainties.

The tailless *Storch* ("Stork") was developed on these lines. Plate 16, Figure 2, shows the *Storch* in model size; Plate 16, Figure 1, in glider size; and Plate 14, Figure 2, as a light-power airplane.

Fitted with an 8-horsepower engine it attained a speed of 125 km./hr., and attracted much attention at the Tempelhof Flying Ground by its speed, maneuvering, and great stability, and gave impressive evidence in favor of this method of designing. The question remains whether gliding is a sound basis for piloting a power airplane. Opinion is divided, but it may be taken that gliding is a sound basis for further training, and soon tests the balance, touch, and eye. But a pupil who has mastered every branch of gliding still requires comprehensive further training when he goes on to power airplane piloting. Of far more importance than the preliminary training in hand and eye, is the extension of piloting experience to the special lore of the currents of the air, gathered in far richer measure during a flight of a hundred kilometers from hill to hill and from cloud to cloud, than in year-long flying on power aircraft. Such experiences will give a new generation of flying

men a body of weather wisdom by which they may safely meet and even turn to useful purpose the atmospheric disturbances so frequently met with in air transport today. Pilots of this school will imitate the exploits of Kronfeld, and so far from fearing wind and weather will master them and ride the storm front in their flights across the land. The true meaning of "air sense" lies in this conquest of the variable atmosphere by the soaring pilot. Just as the master of a great liner must serve an apprenticeship in sailing ships to learn the secret of sea and wind, so should the air transport pilot practice soaring flights to gain wider knowledge of air currents, to avoid their dangers and adapt them to his service.

In confirmation of this view, pilots with soaring experience have shown their special worth in the difficult Lufthansa service across the Alps.

It has not been possible within the limits of this paper to describe more fully the growth of soaring flight, its present activities, its new problems and its future scope. I would call in aid all civilized nations, and particularly your own, in advancing its achievements to a higher level and opening to its activities all regions of the earth, temperate, and tropical.

May I conclude with the hope that the unusual combination of scientific and sporting interest will bring you to join us, in friendly rivalry, in opening the regions of the air to man by means of soaring flight.

# THE FIRST RAINS AND THEIR GEOLOGICAL SIGNIFICANCE[1]

By Assar Hadding

In studying the sedimentary rocks one has to face problems of the most varying nature. I have before had occasion to discuss several of these, especially those related to the formation of conglomerates. In connection with my investigations on these rocks the following questions also arose: Which are the oldest sediments on the earth? Where do they occur? When were they formed? How are they constituted? As will be seen in the following these questions also involved others, and especially one of them—When did the first rains fall on our earth and what was their effect?—must stimulate our fancy. I shall here only present a few reflections, to which these and kindred questions have given occasion.

## THE CONGLOMERATES INDICATE OLDER SEDIMENTARY SERIES OF STRATA

On examination of a conglomerate, pebbles of older sedimentary rocks are often found. These pebbles are naturally of a particular interest in cases where they are the only remains of a series of strata otherwise broken down.

The Lower Cambrian sandstones and the basal conglomerates enclosed in them are the oldest known undoubtedly marine deposits in Sweden. They were formed on the shore of the Cambrian sea during its first transgression. In these conglomerates, however, pebbles of sedimentary rocks, derived from earlier deposited strata, also occur. There is no reason for astonishment at the presence of these pebbles, as from several parts of the country we are aware of sedimentary series of strata of pre-Cambrian age, which are formed in continental basins.

On turning to the pre-Cambrian series of strata, we also find in these only slightly metamorphosed sandstones and shales. But the rocks in the said series are for the most part more or less metamorphic, transformed into quartzites, phyllites, mica-shists, and

[1] From a lecture delivered before the K. Fysiogr, Sallsk, at Lund on Mar. 9, 1927. Reprinted by permission from Geologiska Foreningens i Stockholm Forhandlingar, January–February, 1929.

paragneisses. We can, however, trace these sediments deep down in the Archaean without any difficulty.

On close examination of a conglomerate in these series of strata we find as a rule also pebbles derived from still older sediments. As a natural sequence we ask ourselves: Is it possible to reach the bottom of the sedimentary formations?

## WHEN WERE THE OLDEST SEDIMENTS FORMED?

The sedimentary rocks are mostly deposited in water, and we may without hesitation say that sedimentary rocks have been formed as long as water has existed in liquid state on earth.

When we have got so far in our discussion of the problem this question immediately presents itself: When did water appear in liquid state on earth? We can give no direct answer to the question, but we can make the reflection that, as soon as the temperature of the atmosphere and of the earth's surface falls below the boiling point of water, the atmospheric water begins to condense in the form of rain or dew. When the first rains fall, a new period of earth's history begins. We can infer the conditions of this period by studying the sediments, but we can only comprehend the extent of the change occurring at the transition to this period when the conditions on the earth's surface preceding the condensation of the water are clearly understood.

## THE CONDITION AT THE EARTH'S SURFACE DURING THE PREAQUATIC PERIOD OF THE EARTH

During the time preceding the first condensation of the atmospheric water, during the period which we may call the preaquatic, igneous rocks and to a large extent also gneisses and other metamorphic rocks were formed in the earth's crust. Sediments such as we now find covering the greater part of the earth's surface did not exist, but we can not say that clastic rocks were wholly absent. Loose material was produced as well by the tectonic movements in the earth's crust, at this early period no doubt very violent, as by variations in temperature. The bulk of the loose material on the surface of the earth, however, consisted undoubtedly of volcanic ash. This was carried far by the wind. No water basins existed, in which the ash could get lodged, no water solutions could deposit a cement binding together the grains. Where juvenile gases did not effect cementation, the material remained a loose mass.

An ash-covered earth, no traces of water, no traces of life. A hot surface of earth under a hot atmosphere, rich in water vapor and no

doubt also in ash dust. Volcanic cones and folding mountains of greater height than the present ones, tablelands (future continental platforms) and wide depressions (future oceans), equally void and ash colored. Thus may the earth be pictured before the condensation of water.

Then the first rains fall.

## THE EFFECT OF THE FIRST RAINS

What a wonderful impression is made on us by that which now takes place! Falling drops hit a ground never touched by water, a ground so hot that it has not been able to hold any liquid water. What salts were not to be leached out! How rapidly could not the rills cut deep grooves in the ash! Never have the rivers been so full of mud as during this first condensation. Never have depressions been so quickly silted up, never have the oceanic basins had such a supply of salts, and never has the circulation of water by condensation and evaporation been greater than in this early period.

However, if we do not allow ourselves to be wholly carried away by our imagination of this deluge, consideration will teach us that the progress was not as simple as related above. Certainly the condensation did not set in in such haste as my words perhaps implied. It is not even certain that the first condensation took place around the ash particles in the atmosphere. Perhaps the earth's crust did cool more rapidly than the atmosphere, so that the water was deposited in the form of dew. Perhaps it accumulated below the surface before it appeared on it. Even if the progress was the last mentioned, the formation of dew and rain may have occurred almost simultaneously, provided we measure the time with geological measures. We may expect an answer also to this question, whether the condensation was longest delayed owing to the high temperature of the earth or to the strong radiations of the sun. The problem is intimately connected with the cooling and shrinkage of the sun on the one hand, and with the growing thickness and reduced emission of heat of the earth's crust on the other hand.

We leave the initial time of condensation and turn instead to the epoch when the condensation is in progress and has already proceeded so far that its geological effects have become perfectly distinct. If it had been possible for us to see the changes effected, we should probably, apart from the appearance of bodies of water, have taken most notice of the redeposition of the loose material which has taken place. Subaquatic sedimentation has begun and has made a magnificent start.

How, then, were these oldest subaquatic sediments constituted and how did they occur?

## THE OLDEST SUBAQUATIC SEDIMENTS

The sediments deposited in connection with the first appearance of the seas were of a peculiar type. The material was entirely eruptive, mainly volcanic ashes. A sorting of it according to the size of the grains took place in connection with the transportation but, the material being for the most part and on large areas very fine and uniformly grained, this should have led to no more pronounced stratification.

As the material was loose from the beginning, it could immediately be redeposited without previously being loosened by weathering. Hence it follows that the oldest sediments to a large extent must have possessed the same mineralogical and chemical character as the igneous material (or, to put it more exactly, as the volcanic ashes) from which they were formed. Thus it was not clays, limestones and sandstones that constituted the first subaquatic series of strata but pyroclastic rocks more uniform in their character.

The pyroclastic sediments grew rapidly thicker in larger as well as in smaller basins. In most places the subaquatic sediments rest on aeolian material, and it is not possible to show any petrographical difference between these aeolian and subaquatic parts of the series of strata.

Upon the first, short period, with the formation of exclusively pyroclastic sediments, a second one follows during which the chemical effects of the water begin to be noticeable in the sediments. The leaching out of alkali, lime, and iron was, as mentioned, greater than during any other period in the earth's history, and probably the deposition of lime and iron compounds was very abundant, even though locally limited. A precipitation of for example ferric hydroxide might then as now take place on a very different scale in different basins. Differences in accessions, in the circulation of water, in the evaporative conditions, etc., interrupt the uniformity otherwise characterizing these early periods.

We have hardly occasion in this connection to follow the development further. The next step in the subaquatic sedimentation following immediately upon the one just mentioned, is the formation of sediments abundant in clay and quartz as well as those rich in lime and iron. We then have such a normal formation of sediments as may be followed through the geological periods up to our time.

If the first subaquatic sediments have possessed a peculiar character and have had a magnificent development, one must ask if something of them is not to be found in the earth's crust.

## WHERE ARE THE OLDEST SEDIMENTARY ROCKS TO BE FOUND?

As already preliminarily mentioned, the Lower Cambrian conglomerates contain pebbles from pre-Cambrian sediments, and the conglomerates in the Upper Archaean contain pebbles from earlier deposited sedimentary series of strata. In this way we can immediately follow the formation of sediments back to the Lower Archaean.

If we look for sedimentary rocks in the Lower Archaean, we must however understand that they can not appear in their original form. No part of the earth's crust has undergone so many and so thoroughly metamorphic processes as the oldest one, and in no other part have the rocks been so mixed with injected igneous matter.

Thus we can only expect to find the oldest sediments in a highly metamorphic shape and probably strongly broken up by younger igneous rocks.

In the course of time a great part of these rocks must have been destroyed by erosion or concealed below younger strata and partly also pressed down to such a level that they could partake in a magmatic circulation. What now lies denuded can therefore only be a very small part of what once was formed. We turn to the oldest Archaean regions in search of it.

The two regions to be thought of next are the North American and Fenno-Scandian. Both are well known by the ardent studies pursued for many years by a very great number of geologists, amongst whom we find several of the leading petrographers and geologists of the present and the past generation. Thanks to the works of these students we are at the present day very well able to survey the origin of the Archaean rocks. We shall only turn to the Swedish region. Is there then any cause to suspect that some of its rocks belong to the oldest sediments on the earth? My answer will without hesitation be affirmative, and I am persuaded that everybody, who knows the Swedish Archaean rocks, and who approves of the train of thought I have followed above, must answer in the same manner. And moreover, everybody must come to the same conclusion. The Swedish pyroclastic leptite formation contains the oldest subaquatic sediments on the earth and the limestones and iron-ores connected with this formation bear evidence of the first chemical weathering and differentiation of sediments. We shall discuss the premises of this conclusion.

No doubt, many will immediately object: "The iron ores in the Swedish leptite formation are igneous." Nobody can deny that ore-minerals occur primarily in the igneous rocks and certainly nobody can doubt that iron ores also may occur as products of magmatic differentiation. We have sufficiently good evidence of this in many quarters. But it does not imply that all ores occurring together with

igneous rocks are of magmatic origin. Least of all can we proceed from such a supposition in the case of ores among the Lower Archaean rocks. On the contrary we must, as I have shown above, take for granted that sedimentary iron ores not only can but also ought to be present in the Lower Archaean. The metamorphism to which they have been exposed and the admixture of younger igneous matter, they may exhibit, only make the determination of their primary character more difficult.

The same holds good to a certain extent of the limestones and other para rocks. Besides their chemical character, which indicates a sedimentary differentiation, their occurrence also shows that they belong to a sedimentary series of strata. We find them above the oldest gneisses, that contain neither pyroclastic elements nor rocks formed by sedimentary differentiation (limestones, iron ores, etc.), but they lie below the Upper Archaean with its abundance of fully differentiated sediments. Thus they occur just where the oldest sediments are to be found.

This is not the place to discuss the primary character of the different gneisses or limestones nor to debate as to which ores may be considered of magmatic and which of sedimentary origin. The reason I have dwelt upon these questions has only been to emphasize the necessity of keeping in sight not only that different possibilities of interpretation exist but also that there are undoubtedly different types of rock, igneous and sedimentary, in the leptite formation. There is often great difficulty in judging their character and it is increased by the fact that the rocks formed by sedimentary differentiation, especially limestone and iron ore, frequently appear by subsequent liquefaction in intimate connection with igneous matters.

As already mentioned, the mineralogically and chemically differentiated rocks belong to the second stage in the formation of the oldest subaquatic sediments. The first sedimentation by running and tranquil water consisted of a redeposition of the loose ash-material. When looking for the oldest subaquatic sediments we therefore may expect to find, besides the first sedimentarily differentiated ones, also those with the chemical character of the volcanic ash. These rocks ought, as a matter of fact, to form the greater part of the oldest sediments, and we may take it for granted that they originally had the character of tuffs.

Do then traces of these pyroclastic rocks also exist in the Lower Archaean? Yes, not only traces but large masses. They appear first in the leptite formation and form the bulk of it. It is fully manifested that Swedish leptites as well as the hälleflinta are mostly and often entirely constituted of volcanic ash. It is also known that these rocks occur almost spontaneously in enormous quantities in the Lower Archaean and likewise that they are accompanied by

the oldest known strongly differentiated rocks. I find it therefore logically correct to draw the conclusion from the premises given in the quoted material that the leptite formation is formed on the first appearance of liquid water in the earth.

The reasons of the above-mentioned conclusion may be summed up as follows:

1. Normal subaquatic sediments are found in several places in the younger part of the Archaean. We can easily follow the sedimentary series of strata in a more or less metamorphic shape down to the Lower Archaean. In this then we have to look for the oldest sediments.

2. The Lower Archaean is nowhere easier of access than in Sweden. Therefore we may expect to find traces of the oldest sediments in the Lower Archaean of Sweden.

3. Rocks of sedimentary origin occur in the Swedish leptite formation, which we consider as the upper part of the Lower Archaean. These rocks are partly strongly differentiated (above all limestone and iron ores), partly undifferentiated, of pyroclastic origin.

4. It has not been possible to show any rocks of sedimentary origin in the part of the Archaean that is older than the leptite formation.

As to the progress of formation we may add:

5. Before the condensation of the water the earth's surface was to a large extent covered with loose volcanic ash, which was bound only by juvenile gases and lava beds.

6. By the appearance of liquid water the ash was formed into enormous quantities of tuffs, that soon came to enclose leaching products also, above all lime and iron compounds. The chemical-mineralogical differentiation was gradually accomplished by normal weathering and sedimentation. The pyroclastic rocks then became less conspicuous and normal sediments dominated.

We may sum up the argument thus: The details are debatable but only one opinion on the process as a whole and its general results is possible. From this point of view we must conclude that the leptite formation contains the oldest sediments of the earth, and that these were formed in connection with the first condensation of the water.

## SOME MORE PROBLEMS

Though I have now discussed the problem of nearest interest to me I can not forbear to mention a few more that are directly connected with this. One of them concerns the question: How far back in the earth's history does the first appearance of the water lie?

We are accustomed to use large figures when stating the age of rocks belonging to one formation or another. These figures are

also widely varying according to the estimate of age being made on the one principle or the other. If the age of the oceans is estimated from their percentage of salts to be 50 to 200 millions of years or from their accession of sediments 35 to 400 millions, we still have no satisfactory knowledge of the time of the water's first appearance. From the disintegration of the radioactive elements the age of a great many different rocks has been estimated. According to such an estimate the age of a rock belonging to the Lower Archaean but younger than the oldest sediments would be 1,300 millions of years. It seems probable to me that 1 or 2 milliards of years have passed since the first rains fell on the earth. I shall, however, abstain from any further discussion of this problem, as I can not give any new contribution to its solution. I shall instead draw attention to an attempt to compute the age of the earth at the time of the crust's solidification. Herold Jeffreys at Cambridge published a work in 1924 entitled "The Earth," in which he asserts that the earth's transition from a gaseous mass to liquid form must have taken place in less than 5,000 years. After a further 10,000 years or when the earth was less than 15,000 years old, it had, according to the estimates of Jeffreys, a solid crust of such thickness that the strong radiation of heat was prevented. It may of course be supposed that a good deal of time had still to pass before the water began to condense, but the quoted figures are undeniably amazingly small compared to the millions upon millions of years, by which we compute the age of the following formations.

Another problem of geological interest is the following: Did the first condensation occur somewhat simultaneously all over the globe, or did it start in certain places, for example at the poles? In the latter case an essential part of the enormous percentage of water in the atmosphere would be discharged in certain regions. This would no doubt also have left its marks on the sedimentation. If the inclination of the earth's axis toward the plane of the ecliptic was not too small, the condensation was no doubt begun at the poles and in the winter half year. At any rate this ought to have been the case, if the condensation was longest prevented by the radiation of the sun and not by the heat of the earth. However, I shall also desist from further discussion of this problem and the possible significance of the distribution of the leptites for its interpretation.

Then one more problem, the last one: With the condensation of the water the development of the organic cells is made possible. We may, without running the risk of being refuted, say that no living organisms existed on the earth before the first rains fell. Water accumulated gradually in large and smaller depressions. It was hot or warm water and, in several basins at least, rather strongly saline (or ac-

count of the strong leaching of the volcanic ash and the strong evaporation). Thus the conditions for the origin of life, i. e., for an organic cell's formation and growth, were favorable. It also appears most natural to me to imagine life begun at this time. If an organic cell could be formed in the one pool, it could also be formed in the other, and we then come to the conclusion that the origin of organic life on the earth may be derived from several protoplasms. To explain the appearance of life on the earth by accession of germs from other heavenly bodies is only to push the problem away. It then remains to explain its appearance in the place from where it first comes. We have no occasion to suppose the conditions on other planets to have been more favorable for the formation of a cell than those on our earth.

## SUMMARY

A survey of the problems connected with the first condensation of water on the earth gives us an idea of the significance of this process. The problems are astronomical, geophysical and geochemical, geological, and biological. The size and temperature of the sun as well as the thickness of the earth's crust and the radiation of heat through it were decisive of the temperature in the atmosphere of the earth. The quantity of water and probably also that of dust in the atmosphere were decisive of the temperature of condensation.

The nature of the atmosphere, the movements in it, the possibilities of local (polar) condensation, the formation of dew and rain are other paleo-meteorological problems of great interest.

The conditions of the earth's surface before the condensation, the direct influences of the condensation on the superficial layers, the size and progress of the erosion, the nature and development of the sediments, the nature of the first marine basins, the variations of the salinity in different basins and in the oceans on the point of formation are circumstances that may possibly become objects of investigations and computations.

The division of land and sea also becomes an actual question by the appearance of water.

The chemical weathering and leaching out of soluble salts begins first after the condensation of water. The chemical sorting of the material takes place simultaneously as well as the cementation by the precipitation of substances dissolved in water. All the rocks formed by sedimentary differentiation belong to the period after the condensation.

Finally I draw attention to the biological significance of the condensation. This and this only made it possible for the organic cells to develop and continue to live on the earth.

The first rains, or perhaps more correctly the first condensation of the atmospheric water, are of perfectly revolutionizing significance, geologically, geochemically, and biologically. There would be reasons to call the preaquatic time the primeval of the earth and the time between the first condensation of water and the more general appearance of determinable forms of animals the prehistoric time of the earth and, finally, to refer the remaining younger parts to the historic time of the earth. At any rate, the significance of the first condensation of the water is not overestimated by this, that the time of its appearance is made the boundary between two of the greatest periods in the earth's history of evolution.

As I already preliminarily stated, I only present a few reflections here. I have hinted at the problems, and if I, with regard to the geological ones, have also dared to make some suggestions as to their solution, I have made them, fully conscious of the fact that the problems are still equally fresh and alluring and in many points quite unsolved.

# WEATHER AND GLACIATION[1]

By Chester A. Reeds

## INTRODUCTION

Weather as it affects glaciation is a subject which has been under observation during the past century. Remnants of the last glaciation still exist in Greenland, Antarctica, and on some of the islands of the polar regions and in the high mountain fastnesses of the temperate and tropical zones. Weather conditions are modifying these ice masses; in fact, the variability of the weather causes glaciers to grow at certain times and wane during other periods. The changes that are going on to-day are apparently similar to those that took place during past ages.

There is a distinction between weather and climate. Climate is the average of normal conditions of the atmosphere, while weather constitutes the variations from the normal. Weather changes are of a day-to-day occurrence. When averaged for the year and for longer periods, they yield differences which make the weather of one year vary from that of another, as well as for groups of years.

During the last decade a few meteorologists have correlated weather changes with variations in solar radiation. This correlation has been specially emphasized by H. H. Clayton in his volume, World Weather, 1923. The correlation of changes in glaciation with solar radiation variations has been mentioned by various scientists, but it has not been discussed in the light of recent developments. In this paper special application of these changes to glacial deposits at Haverstraw, N. Y., and New Haven, Conn., will be made.

## THE CONDITIONING OF ICE SHEETS AND GLACIERS

There are two opposing factors which modify ice masses—namely, nourishment and depletion. Nourishment consists primarily of snowfall, hoar frost, rime, glaze, sleet, and needles, or spiculae, sometimes referred to as "frost snow" or "polar snow." According to Antevs (1929), depletion occurs through melting, evaporation, discharge of bergs, etc. Melting, which is the most important agent, takes place through high temperature, insolation, and to a minor degree from

[1] Address before section E of the American Association for the Advancement of Science, Dec. 27, 1928. Reprinted by permission from the Bulletin of the Geological Society of America, vol. 40, pp. 597–630, Dec. 31, 1929.

rain, air, wind, and water. Glaciers advance after heavy winter precipitations followed by low summer temperatures and cloudiness. They retreat following slight winter snowfalls, high summer temperatures, and clear sky.

It has been said that the cause of the principal variations in the present size and condition of glaciers in Alaska is due to variations in altitude, in latitude, in precipitation, and in direction of slope (Tarr and Martin, 1914). Fluctuations in Alpine glaciers have been traced back to about 1600 A. D.; in Norwegian glaciers, to about 1700 A. D. Yearly measurements were begun on the Rhone Glacier in 1874 and on other glaciers in various parts of the world since 1894. Weather changes are not immediately recorded at the terminal end of an ice mass, since glaciers vary as to size of the névé field, depth of the catchment basin, width of the fern field, length of the ice tongue, etc. For example, small glaciers in the Alps began to advance in 1909 and 1910; medium-sized glaciers in 1912 and 1913, while long valley glaciers, such as the Aletsch, did not advance until 1920, when it moved forward 120 feet, and a greater amount in 1921. The variability of the weather thus causes glaciers to advance or retreat, but not all at the same time; for, being of different sizes, their respective masses, as well as other factors, tend to govern their movements.

## SOME PROPERTIES OF ICE

Under the influence of heat, ice behaves as most solids do, contracting when cooled, expanding when heated. As regards the evaporation of ice, it was shown by Barnes and Vipond in 1909 that it goes directly into vapor without passing through a preliminary liquid phase. The melting point of ice is lowered by increase of pressure. The rate at which this occurs is 0.0075° C. for every atmosphere of pressure. This fact was theoretically predicted by James Thomson in 1849 and demonstrated by Sir W. Thomson (Lord Kelvin) in 1850.

Although there is no rise of temperature accompanying the melting of ice, a definite quantity of heat is absorbed—namely, about 80 calories per gram, or 78.818 thermal units. The same amount of heat is evolved when water becomes ice—that is, the amount of heat required to convert ice into water, or vice versa, would raise the same amount of water through 80° C. This is the latent heat of fusion of ice or the latent heat of water. Because of this fact, ice is the most difficult of all solids to melt, as regards the amount of heat energy required to be put into it in order to effect fusion, and water the most difficult liquid to freeze of all substances, owing to the relatively large amount of the latent heat needed. It is fourteen times as great as for lead and twenty-eight times as great as for mercury.

The temperature at which water reaches its maximum density is 39.2° F. (3.945° C.), according to the researches of Joule and Playfair. When cooled below this temperature water expands instead of contracting, and the expansion goes on to the total extent of $\frac{1}{10000}$ of its bulk, until freezing occurs, at 32° F. (0° C.), when there is a sudden expansive leap of nearly a tenth of the whole volume of the water as it freezes to form ice.

The X-ray study of ice crystals by Sir William Bragg (1925) shows that ice contains an open hexagonal lattice structure consisting of four molecules of water. This lattice structure reveals why ice can be melted under pressure and how it is possible for water (with the molecules closely compressed) to occupy less space than ice. It also accounts for the sudden and relatively enormous expansion which occurs when water freezes. On becoming ice, the water has increased in bulk by 9 per cent, and this increase occurs instantaneously and with enormous, well-nigh irresistible, force. It also explains why ice is lighter than water and why ice floats on lakes, rivers, and the open sea with about one-tenth of its volume above water level.

The fresh water of lakes continues to contract with increasing cold. The surface waters, being colder, and thus heavier, sink, and the warmer waters from the bottom rise to the surface. The convection currents thus set up continue until all of the water in the lakes has been reduced to the maximum density of water, after which the circulation stops, for the surface waters, when cooled to lower temperatures, remain on top and grow steadily colder until they suddenly freeze at 32° F. (0° C.).

## SOLAR RADIATION VARIATIONS

The sun's rays supply nearly all of the heat of the earth's surface. They affect not only the weather, but also insolation and temperature, two of the agencies conditioning ice masses; hence a brief consideration of solar radiation is important in discussing weather and glaciation.

In 1837 Pouillet invented the pyrheliometer, with which he endeavored to measure the heat of the sun. Violle, Crova, Chowlson, and the Ångströms followed him and increased the knowledge of the subject. Langley invented the bolometer for studying the selective absorption and the scattering of light in the atmosphere. With this instrument he measured, during 1902, 1903, and 1904, the solar radiation, corrected for atmospheric influence, and announced that the intensity of solar radiation is subject to irregular variations due to conditions in the sun itself.

More recently Dr. C. G. Abbot, Secretary of the Smithsonian Institution, has improved the instruments and methods of Langley

and determined the mean of the "solar constant" to be 1.938 calories per minute per square centimeter. Solar radiation is subject to variations which, although slight, are important. The value of the "solar constant" at a given time may differ from the mean. The highest monthly mean for the years 1918 to 1929 was 1.969 for September, 1921; the lowest, 1.912 for July, 1922, giving a range of 0.057, or 2.9 per cent. The highest yearly mean for the same period was 1.952 for 1921, and the lowest 1.927 for 1922, or a range of 1.3 per cent, according to solar constant values supplied by Doctor Abbot in a personal communication of November, 1929.

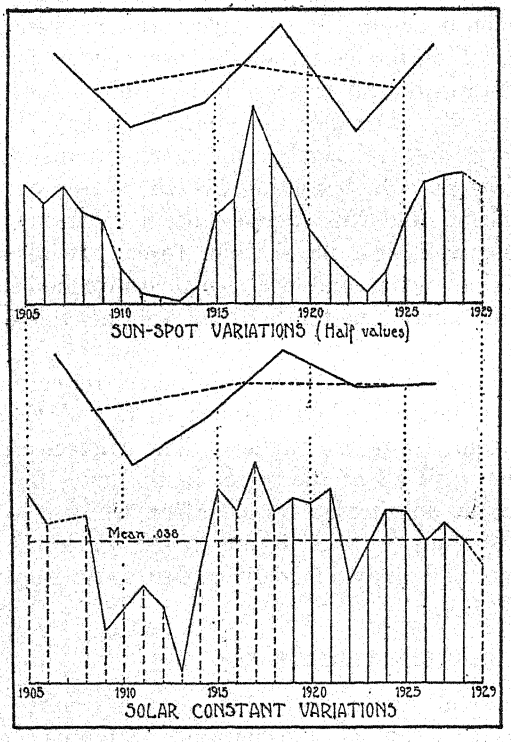



FIGURE 1.—Graphs of solar constant and sun-spot variations 1905 to 1929

Curves smoothed by taking the mean of successive four (solid line) and eight (dotted line) years, appear above each graph. In the solar-constant graph the vertical lines have been dotted where the data were incomplete for the year. (Data from Dr. C. G. Abbot, November, 1929.)

The "solar constant" variations for the period 1905 to 1929, inclusive, have been arranged in the form of a graph, Figure 1, by entering the yearly mean fluctuations on the ordinates and the years on the abscissa. This is the same method and grid used in Figures 2 to 13 for the varved clays. The value, 1.900, is equivalent to the base line. The original drawing has been reduced one-half during publication.

According to Wolfer's sun-spot numbers, there was a maximum of spots in February, 1907, a minimum in May-June, 1913; a maximum in August, 1917, a minimum in August, 1923, and a maximum in July, 1928. These figures, when compared with the solar radiation values, as noted in Figure 1, show a relation between them in the 11-year cycle. Abbot (1929) states that the solar radiation rises to a maximum with medium sun-spot numbers and declines thereafter as sun-spot numbers increase. Furthermore, superposed on the sun-spot influence variation there appears to be three pulses of regular periods of about 25, 15, and 11 months respectively, and

of amplitudes which are large enough, when combined in similar phase, to nearly overpower the maximum sun-spot effect on the solar-constant values.

The 1905 to 1929 monthly averages of sun spots show little apparent relation with that of solar radiation. The yearly means, however, 1905–1929, exhibit a more evident comparison. A closer resemblance between the two is secured when the 3 to 4 year oscillations in solar radiation, which are not appreciable in sun spots, are smoothed by means of four, and further smoothed by taking the means of each consecutive two means, Figure 1, as was done by Clayton (1923).

According to Abbot (1926), the intensity of solar radiation is expected to increase when sun spots are numerous. However, when an individual sun spot crosses the central part of the sun a depression in solar radiation is usually noticeable, which is attributed to a sort of cloudiness over each sun-spot group. The resulting depressing effect may exceed one of increased radiation. Thus it may be said that there is a real relation, though not a very close one, between sun spots and solar radiation.

## EFFECTS OF ATMOSPHERIC OPACITY

The radiation from the sun which reaches the earth is considerably reduced by the opacity of the earth's atmosphere. According to H. N. Russell (1926), only about 70 per cent of the initial solar radiation gets through to sea level when the sun is at the zenith and the air is free from dust and clouds. The opacity increases as the sun approaches the horizon, due to the greater distance the rays have to travel through the atmosphere and the loss of the shorter rays by diffraction. The only satisfactory way of dealing with these variations is to measure with the spectrobolometer the energy received when the sun is at various altitudes. Each different wave length has to be measured separately to determine the depletion for each and the various amounts summed up to find the total solar radiation outside the atmosphere. The process is definite, but laborious.

Normal opacity of the air may be much increased by the presence of four by-products, which may be regarded as factors that affect solar radiation—namely, water vapor, carbon dioxide, ozone, and dust. Water vapor has the most thermostatic influence. In tropical regions, where the humidity is high, nearly half of the sun's heat is absorbed by a cloudless sky. A cloud surface may reflect more than 70 per cent of the sun's rays and absorb a large part of the remainder, while a canopy of dense clouds may permit only a small part of the sun's radiant energy to reach the earth. Since carbon dioxide and ozone are present in the air in very small quantities, their influence is subordinate to that of water vapor. Ozone probably absorbs

some of the solar radiation, since laboratory experiments tend to show that it does.

Dust in the air causes a decrease of the solar radiation reaching the earth. When dust is blown to heights of 10 to 50 miles by volcanic eruptions—that is, into the isothermal region or stratosphere—the direct solar radiation at high sun may be reduced as much as 20 per cent, as was noted following the Katmai eruption of June 6, 1912. Not all great volcanic eruptions decrease the surface temperatures of the earth, but only those that drive a lot of dust into the isothermal region of the atmosphere. Volcanic eruptions during historic times and their influence on solar radiation and the weather have been traced. Such eruptions may have accounted for many of the great changes in the weather that the earth has experienced. W. J. Humphreys has accepted this view and formed his vulcanism theory of glaciation.

Humphreys (1920) considers the average size of the volcanic dust particles in the stratosphere to be 1.85 microns. He calculates that it would require about one year for such particles to fall from an elevation of 35 km. to the lower limit of the stratosphere, which has an elevation above sea level of 17 km. in tropical latitudes, 11 km. in middle latitudes, and 6 km. in polar regions. He considers the finest volcanic dust, which may have reached an altitude of 40 to 80 km. following the eruption of Krakatoa in 1883 and Katmai in 1912, and which encircled the earth a number of times, to have taken two and one-half to three years to reach the base of the stratosphere, or upper cloud level. He estimates that the total quantity of volcanic dust required to cut down the intensity of the direct solar radiation by 20 per cent to be only the 174th part of a cubic kilometer, or the 727th part of a cubic mile, assuming that the particles are spherical. Since the particles are more or less flat, it is probable that not more than the 1,500th part of a cubic mile, or the 350th part of a cubic kilometer, is needed to reduce the intensity of direct solar radiation 20 per cent. This amount, if indefinitely continued, he concludes, would be capable of producing an ice age.

With the particles all being 1.85 microns in size, he calculates that the volcanic dust is some thirtyfold more effective in shutting out solar radiation than it is in keeping terrestrial radiation in. This is because radiation, both solar and terrestrial, is simply scattered by such small particles and scattered in proportion to the inverse fourth power of the wave length. Since the ratio of solar wave length to terrestrial wave length is, roughly, 1 to 25, and the ratio to their fourth powers as 1 to $39 \times 10^4$, it follows that the interception of outgoing radiation by the very finest, and therefore most persistent, dust is wholly negligible in comparison with its interception of incoming solar radiation.

## SOLAR RADIATION AND THE WEATHER

Since 1915 H. H. Clayton, retired, formerly chief forecaster for Argentina, has been using the averages of groups of high, medium, and low solar radiation values of the Astrophysical Observatory of the Smithsonian Institution in attempting to correlate them with atmospheric changes on the earth. He has compared these means with the means of temperature and pressure variations scattered over the earth and attained results which show systematic changes which seem difficult to explain on any other grounds than a real relation.

The more usual solar fluctuations are irregular and occupy a few days or weeks. Clayton (1923) obtained the best comparisons of day-to-day fluctuations by averaging the values of each phenomenon in groups of 5, 10, or more days, after allowing, in some instances, an interval of 3 days for a lag in the effect. He noted a tendency to short-period variations in 3.5, 7, and 13.5 days, which he attributed to successive outbreaks of faculae on the solar surface. Traces of similar tendencies in the weather were also observed.

Clayton also noted solar radiation values of similar kind at intervals of about 11 and 16 days, which he correlated with the movement of heated gases from one side of the sun to the other. These heated gases are associated with solar faculae. He observed similar variations in temperature at Buenos Aires in 1921.

In addition to the day-to-day variations, Clayton has averaged those for monthly, yearly, and longer periods and established an intimate relation between them and those of the weather. He observes that the complexity of the weather changes arise from complexities of solar radiation in which changes of short period are mixed with progressively longer waves of change going up into years and centuries.

Clayton has shown that with an increase of solar radiation the temperature rises and the pressure falls in equatorial regions and is immediately followed by a rise of pressure and a fall of temperatures in temperate regions, reaching a maximum between latitudes 40° and 60° north and south. Over the oceans, in still higher latitudes, 60° to 70°, the relation is again direct, as in the tropics—that is, the temperature rises and the pressure falls with increase in solar radiation. From the region of maximum rise of pressure, a wave of returning pressure starts toward the Equator with a velocity inversely proportional to the length of the solar cycle and drifts eastward with the eastward drift of the atmosphere, dying out in low latitudes. This effect is true, whether the increase in solar radiation be for a few days, for months, for years, or for longer periods. With the solar radiation below normal, the effects for the different regions for the same time of year are the reverse of those when there is an equivalent excess of solar radiation.

As noted by Clayton, the monthly means of solar radiation and those of temperature and pressure show that with an increase in intensity of solar radiation the maxima of pressure form over the coldest parts of the temperate zones, which are the continents in winter and the oceans in summer. The more intense the radiation, the farther north and south are these maxima of pressure formed. The abnormal distributions of temperature and precipitation are intimately related to the distribution of pressure. Thus the centers of action move north and south of their mean position with the varying intensities of solar radiation. There is a lag in the solar effect near the centers of action proportional to the duration of the solar change. In general the lag is about one-twelfth of the length of the interval from maximum to maximum or minimum to minimum. The lag may vary from a few hours to a year, depending on the duration of the effect.

The year-to-year variations in solar radiation are shown by Clayton to be connected with year-to-year variations in rainfall and river heights in North America, South America, and Australia. He also observes that the solar measurements clearly indicate the existence of a 3 to 4 year change in solar radiation, which is reflected in a 3 to 4 year change in pressure, rainfall, etc. This he attributes to a variability in the intensity and amount of faculae on the surface of the sun.

Clayton's studies of the effect of maximum and minimum sun-spot periods on the weather show that the pressure is lower at the time of maximum sun spots in the equatorial zone, especially in the humid regions, at all times of the year. The differences of pressure are, however, much less than in the case of the monthly means. Koppen has shown that the mean temperature of the surface air over the globe was lower at sun-spot maximum than at sun-spot minimum. Although much has been written concerning the effect of sun spots on the weather, investigators agree that weather conditions are far more variable than sun-spot numbers.

## RECORDS OF WEATHER CHANGES EXTENDING OVER MANY YEARS

Weather changes extending over long periods of time are reflected in the annual growth rings of trees (Douglass, 1909, 1914, 1919, 1928, 1929; Huntington, 1914). Harris (1926), in considering the correlation between sun-spot numbers and tree growth, concludes that the coefficients indicate a low positive correlation between them, but the relationship is by no means so intimate as many writers imply.

The best-preserved records of weather affecting glaciation are found in the aqueo-glacial deposits of Pleistocene age, which preserve seasonal, annual, and longer period variations. The deposits are commonly known as laminated or varved glacial clays.

These laminated glacial clays, which record the annual retreat and ablation of the last continental ice sheet, have been studied, during the last 20 years, in North America, Sweden, Finland, Iceland, Argentina, and the northwestern Himalaya Mountains of India. While the primary object of the investigation has been the establishment of a geochronological time scale, with the varve or year as the unit of measurement, a study of the variations in thickness preserved in the seasonal and annual layers is of special interest, since it involves weather changes which affected the melting of the ice during its retreat.

The material composing the varved clays was brought directly from the melting ice by subglacial streams and deposited in fresh or slightly brackish water lying in front of the receding ice mass. The mud was brought into the lake during the annual melting period—that is, the summer months. The quantity delivered was in all probability proportional to the quantity of ice that underwent melting. It apparently was not directly influenced by the nourishment of the ice as was the retreat of the ice front. Thick varves thus signify a long period of warm summer weather; thin varves imply short summers, with cold and foggy weather. The varve graphs which have been published, showing summer and winter thicknesses, record fairly accurately the yearly variations of the amount of summer temperature.

The lamination of the clay sediments postulates a strict periodicity, not only in the melting of the ice and the deposition of the "summer" layer, but a pause of several months, during which time the supply of sediment is interrupted and the fine clay particles, which remain suspended in the fresh-water lakes following the summer influx, have had sufficient time to settle to the bottom and form the dark "winter" layer, consisting of pure clay. No phenomena other than seasonal variation—that is, the alternation of summer and winter—meets this postulate. Varved clay sediments produced by this seasonal variation are being deposited now in Lake Louise, Alberta, Canada (Johnston, 1922).

In addition to the seasonal variation, there is an annual or varve variation in which changes in thickness occur from year to year. The thickness of the varves usually varies in different basins from a few millimeters to 3 or 4 cm., sometimes more. For instance, the varves in the Hudson River Basin at Haverstraw, N. Y., average 35 mm. (1.38 inches) in thickness, while those in the Quinnipiac Basin, near New Haven, Conn., average 23.24 mm. (0.92 of an inch). The relative differences as well as other structural features, however, remain constant over wide regions as well as over widely scattered occurrences. Thus it is possible to identify and correlate the varves in separate sections.

With samples of the material in hand the correlation is often effected by a comparison of the variations in thickness, color, or peculiar lamination of successive varves or groups of varves. The seasonal and yearly variations are also noticeable when measuring the thickness of the sediments in the field on strips of paper. Their relative values, however, are made more apparent when plotted graphically, according to a method initiated by Gerard de Geer, of Sweden, in 1906. The diagram consists of a horizontal base line from which arise a number of vertical lines spaced one-half centimeter apart. These equally spaced lines on the abscissa are numbered to represent the varves or years. The thickness of the successive varves from the bottom upward are entered as ordinates from left to right on the successive vertical lines and the tops united with one another to make them stand out more effectively. A comparison of such diagrams representing different sections brings out whether they are common varves and how they are related to one another. (Fig. 2.)

Varved clays are extensively represented in the Pleistocene epoch (De Geer, 1910, 1912, 1921, 1926, 1927*a*, 1927*b*; Antevs, 1922, 1925, 1928; Norin, 1927; Reeds, 1926, 1927; Sauramo, 1923, 1929; Sayles, 1919). They are also represented in glaciations older than the Pleistocene (Antevs, 1925; Reeds, 1923; Sayles, 1914; Schuchert, 1914; Süssmilch and David, 1919).

## FLUCTUATIONS IN HAVERSTRAW AND NEW HAVEN VARVED CLAYS

In order to investigate the possible relation between varved clays, glaciation, and weather, the laminated clays at Haverstraw, N. Y., and New Haven, Conn., have been measured, correlated, and specially diagramed. The Haverstraw clays extend along the west bank of the Hudson River from a mile south to 2 miles north of the town and reach inland one-half mile from the river front. These clays vary in thickness from 50 feet in a 60-foot terrace facing the Hudson River in west Haverstraw to more than 100 feet in the low plain bordering the river bank. The New Haven clays occur in the low-lying Quinnipiac River Valley, in the eastern portion of the city.

The varves in the Haverstraw clays were measured, correlated, and diagramed by Chester A. Reeds and Ernest Antevs, working independently. The Reeds diagram of 736 varves was shown and accompanied by abstracts at the Cleveland, 1927, meeting of the Geological Society of America, while Antevs' Haverstraw curve appeared in March, 1928, in his book, The Last Glaciation, published by the American Geographical Society, Research Series No. 17, as graphs marked New Haven A1, B1, Plate I; A2, B2, A3, B3, A4, Plate II. The New Haven varved clays, which Antevs correlates with Haver-

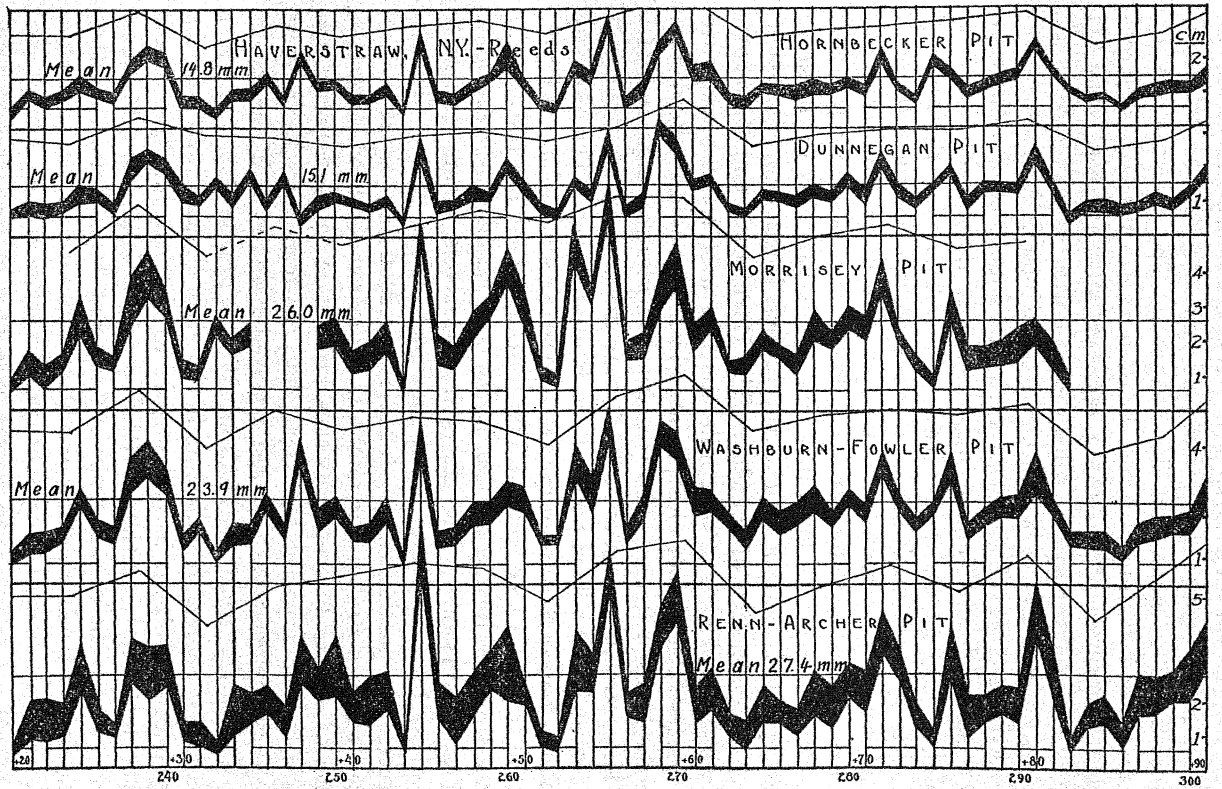



FIGURE 2.—C. A. Reeds' correlation of 70 varves occurring in five separate clay-pits at Haverstraw, N. Y.

Thickness of winter layers indicated by black shading. The smoothed curve appearing above each of the five graphs has been developed by averaging the varve measurements in groups of four, as indicated by the broken line near the base of each graph. The Hornbecker and Dunnegan pits appear in a 60-foot terrace bank; the other pits have been dug into the floodplain of the Hudson River.

straw, also appear diagramed and described in his report as graphs labeled New Haven, C2, C3, Plate II.

In Figure 2 appears an example of the correlation which Reeds has made of the varves occurring in five separate clay pits at Haverstraw, N. Y. Seventy varves, with field numbers +20 to +90, serial numbers 231–301, appear on this diagram. The thickness of the "summer" and "winter" layers in each varve has been differentiated, the "winter" band being represented by a black shading, the "summer" layer by the ruled vertical line extending from the base line upward to the beginning of the winter layer in each section. Five such graphs, one for each pit, appear on the diagram. As the curves closely simulate one another in their oscillations, the correlation may be said to be firmly established. The thickness of the varves in each graph has been averaged and the mean for each determined, as follows: Hornbecker pit, 14.8 mm.; Dunnegan pit, 15.1 mm.; Washburn-Fowler pit, 23.9 mm.; Morrisey pit, 26.0 mm.; Renn and Archer pits, 27.4 mm. This variation in thickness of the deposits is attributed primarily to their location and elevation, during the deposition of the clay. The Hornbecker and Dunnegan pits, which are a quarter of a mile apart in west Haverstraw, have been cut into the 60-foot escarpment, which is one-half mile distant from the Hudson River. The Washburn-Fowler pit, a quarter of a mile long, stretches lengthwise from near the floor of the Dunnegan pit eastward on the flood plain of the Hudson River. The Morrisey and Renn-Archer pits are deep ones, appearing south of Jones Point, near the Hudson River front, in Haverstraw. They are fully a mile southeast of the Hornbecker, Dunnegan, and Washburn-Fowler pits, in West Haverstraw. The Haverstraw deposits, when contrasted with those in West Haverstraw, show not only a greater average thickness, but particularly so for the corresponding winter layers. These variations are due, no doubt, to a greater depth of water and volume of sediments over the Jones Point area in Haverstraw, although farther from the ice front, than the terrace banks in West Haverstraw, which were fartheest removed from the main channel of the glacio-fluvial river, the Hudson. With a greater depth of water and a larger volume of sediments in the main channel than near the margins of the lake, it is not surprising that during the winter months more clay particles settled down through the cold milky waters to form the thicker "winter" layer at Jones Point than that on the sites of the Hornbecker and Dunnegan pits. Each of the five curves has been smoothed by taking the average of each four successive varves. The smoothed curves have been entered as single-line graphs above the other curves by using the mean of each section as a base line. A comparison of these smoothed curves shows a close agreement in all of the pits. These smoothed graphs represent a

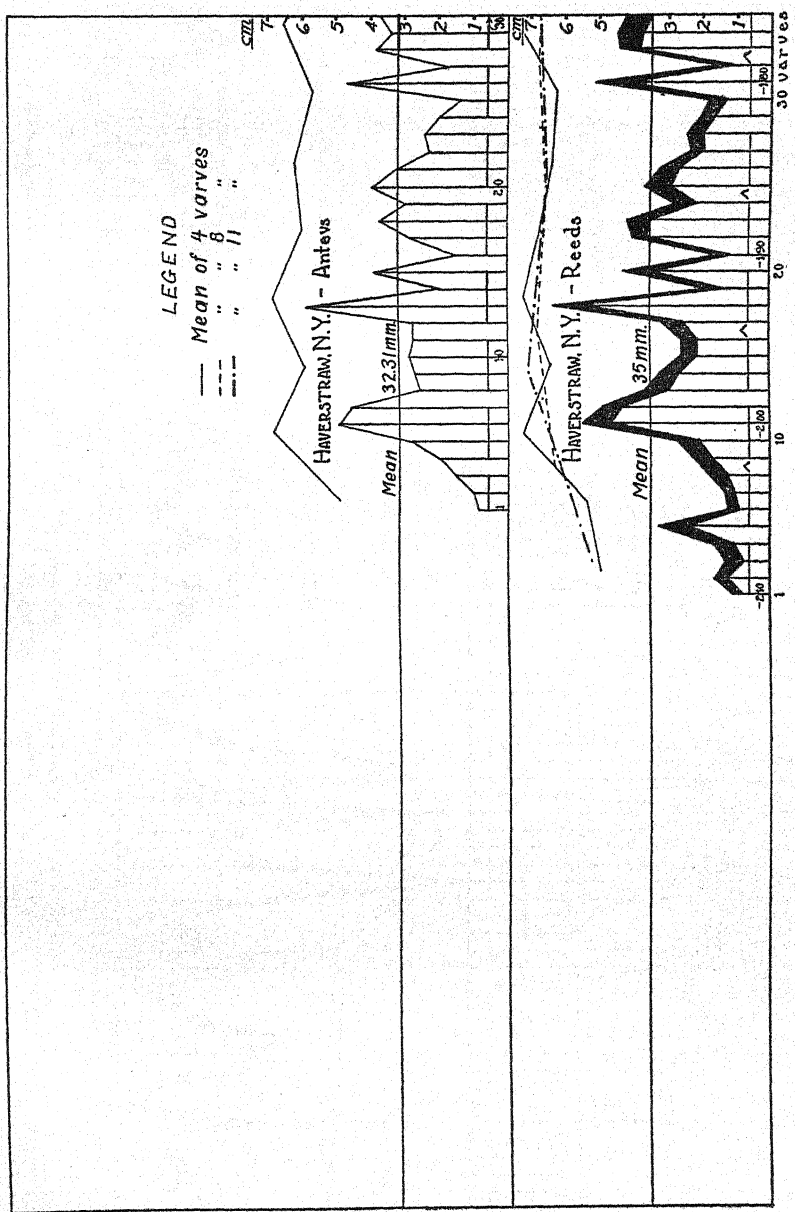



FIGURE 3.—"Normal curves" of the lowest varves in the Haverstraw, N. Y., Clays
As determined by C. A. Reeds and E. Antevs, working independently. Base not reached. Thickness of winter layer represented by dark shading in Reeds' curve. Smoothed curves by Reeds have been placed above each graph.

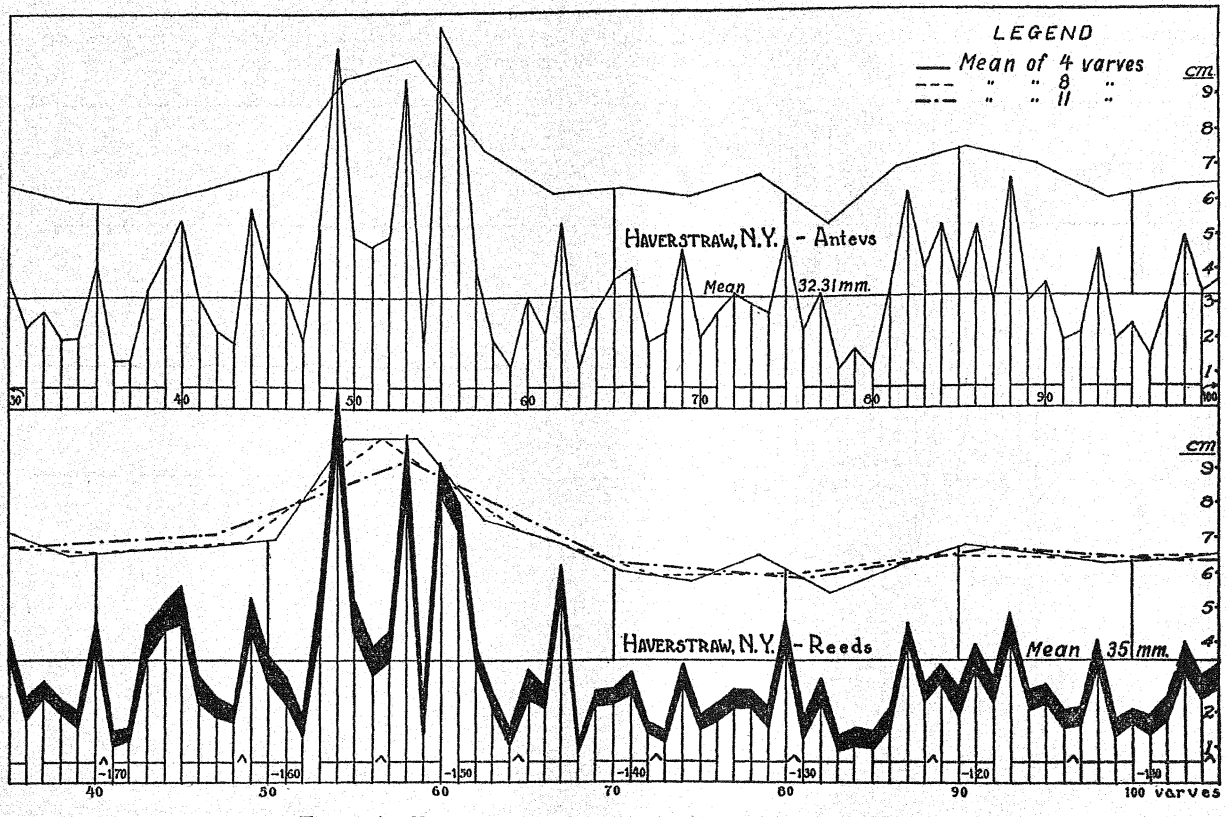



FIGURE 4.—Normal curves of varves 35–105 at Haverstraw, N. Y.

As determined by C. A. Reeds and E. Antevs, working independently. Smoothed curves and means by Reeds in this and the following diagrams.

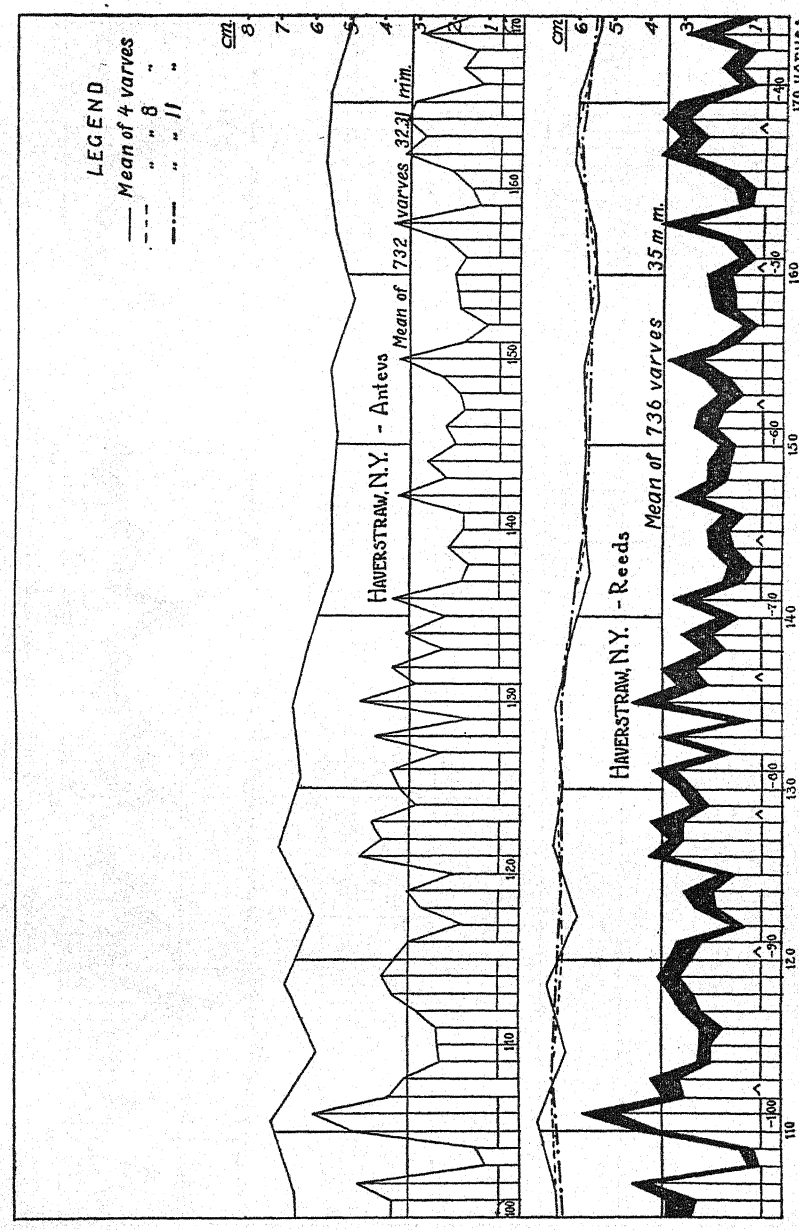



FIGURE 5.—Normal curves of varves 95–175 at Haverstraw, N. Y.
As determined by C. A. Reeds and E. Antevs, working independently.

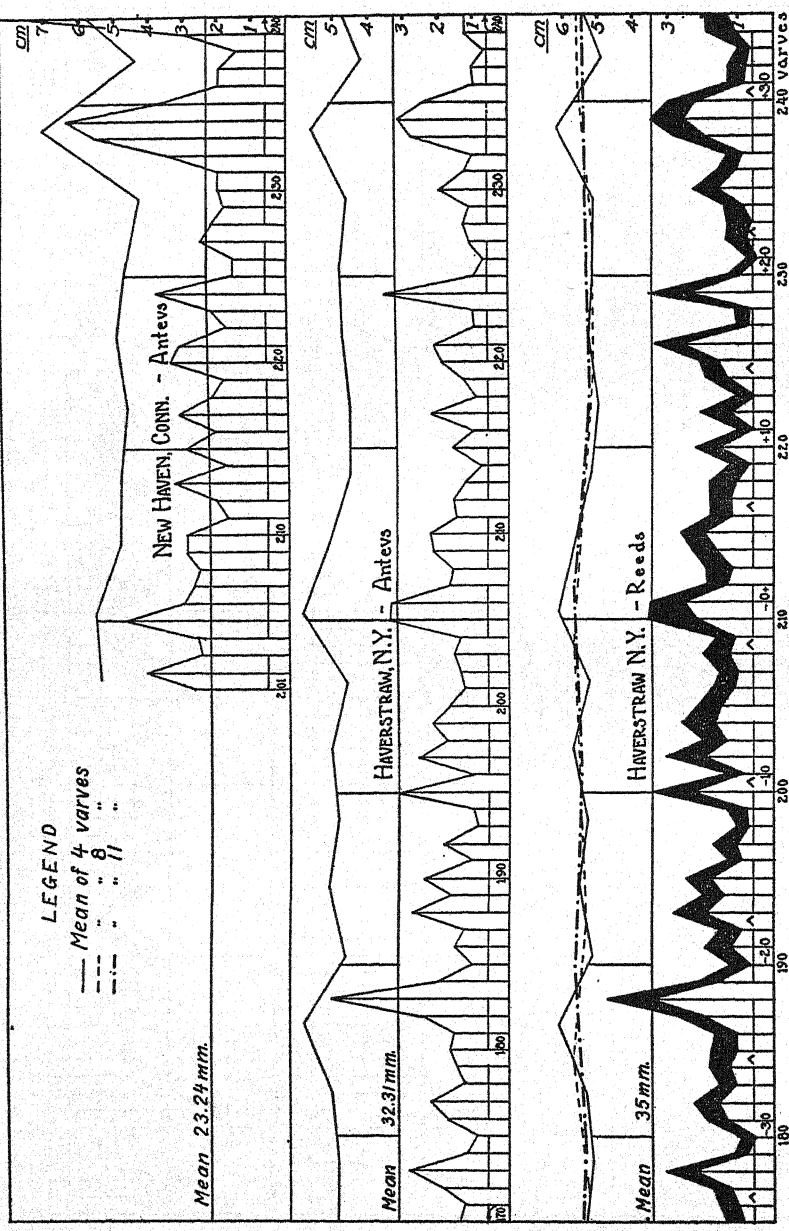



FIGURE 6.—Normal curves of varves 175–245 at Haverstraw, N. Y., and New Haven, Conn. As determined by C. A. Reeds and E. Antevs, working independently.

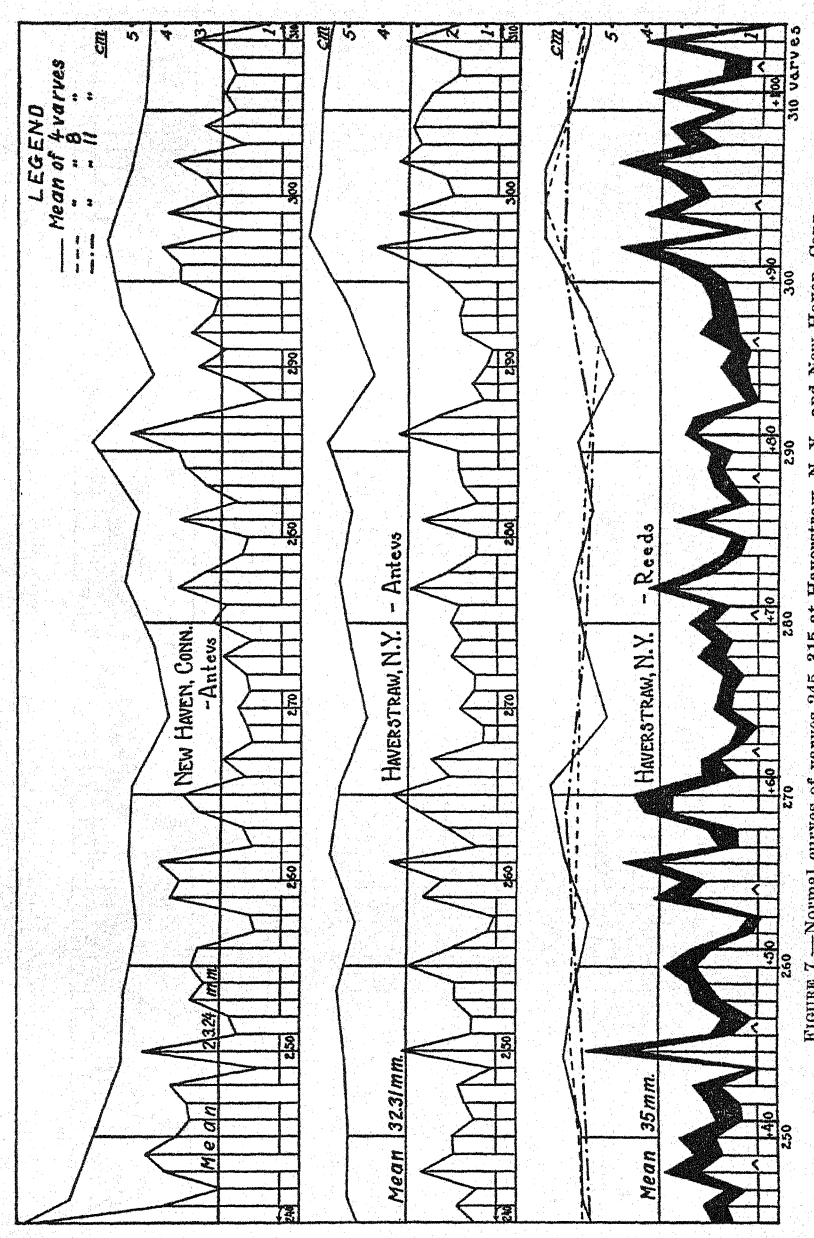



FIGURE 7.—Normal curves of varves 245–315 at Haverstraw, N. Y., and New Haven, Conn. As determined by C. A. Reeds and E. Antevs, working independently.

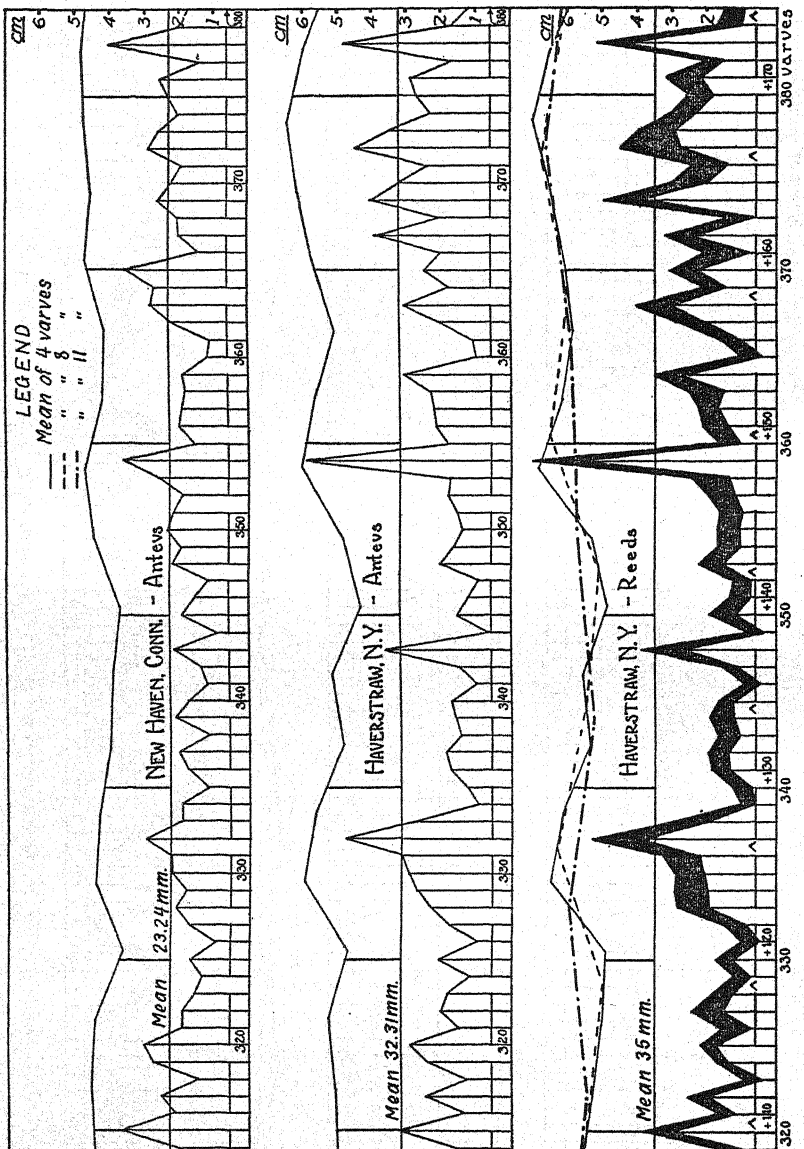



FIGURE 8.—Normal curves of varves 315–385 at Haverstraw, N. Y., and New Haven, Conn. As determined by C. A. Reeds and E. Antevs, working independently.

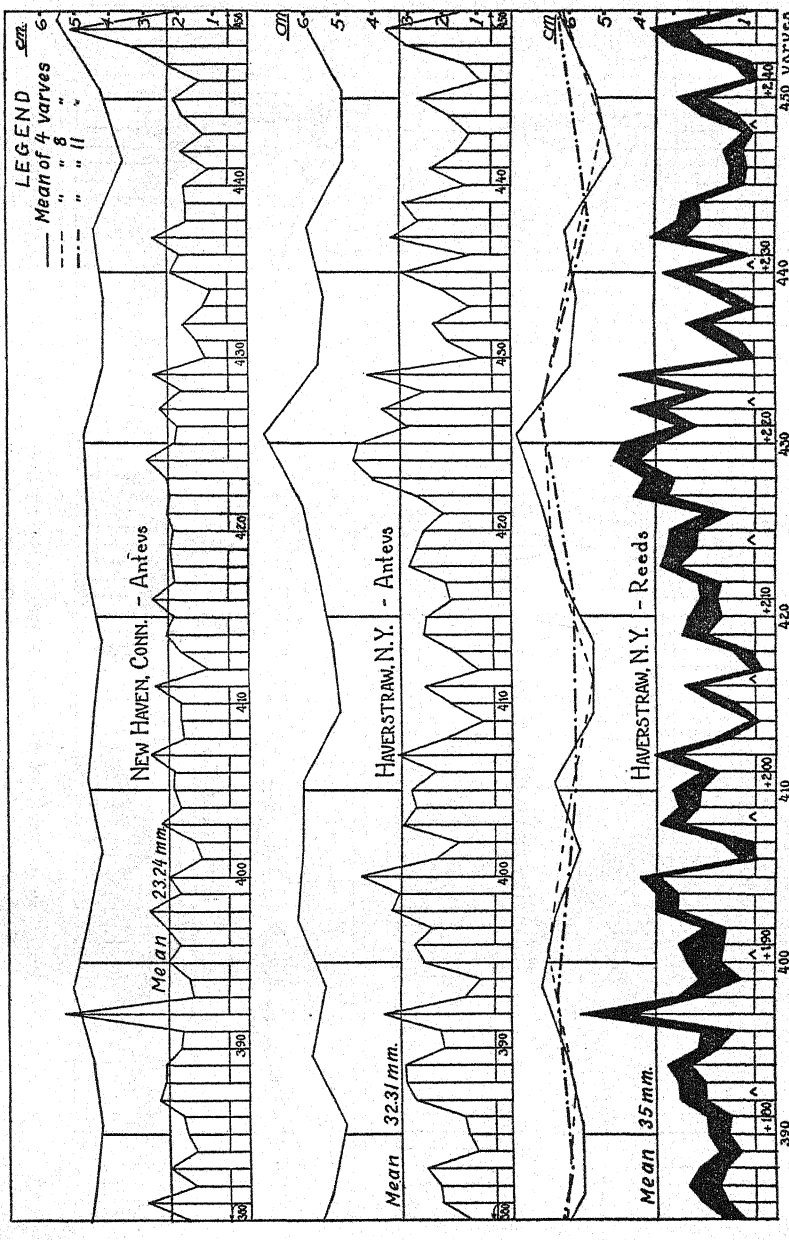



FIGURE 9.—Normal curves of varves 385–455 at Haverstraw, N. Y., and New Haven, Conn. As determined by C. A. Reeds and E. Antevs, working independently.

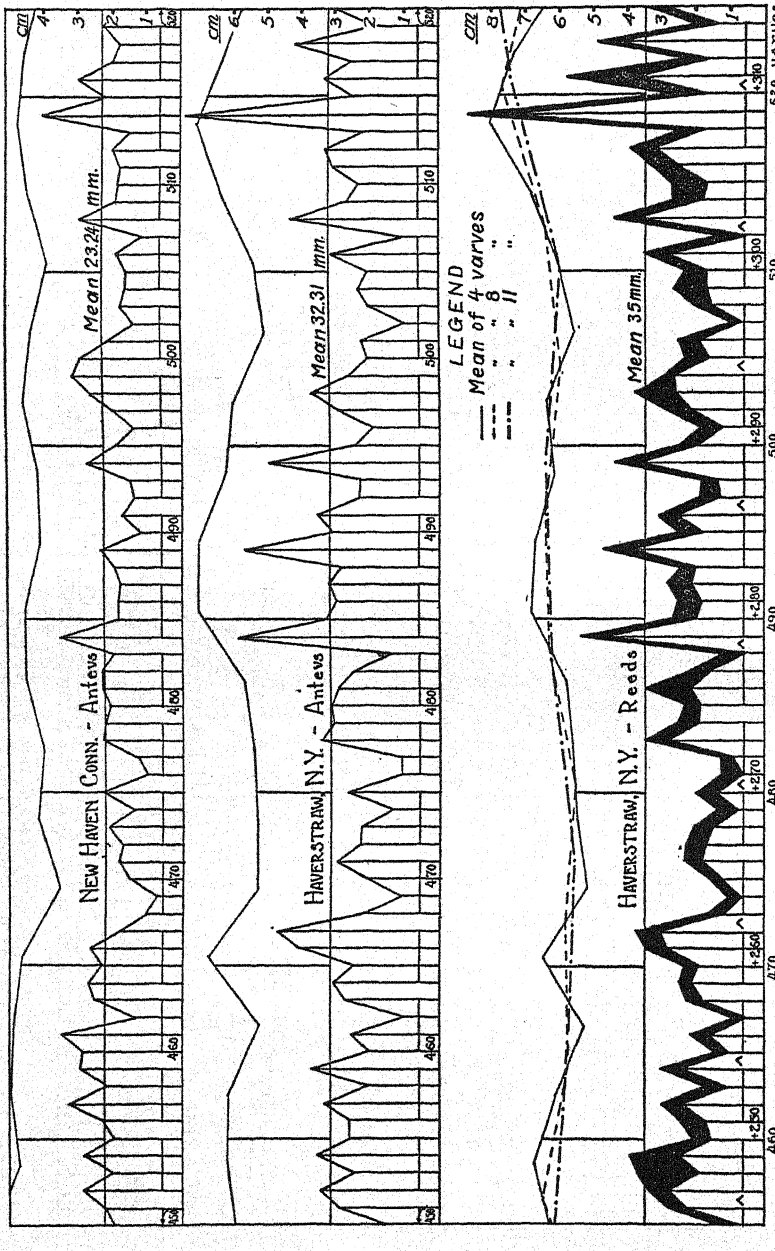



FIGURE 10.—Normal curves of varves 455–525 at Haverstraw, N. Y., and New Haven, Conn. As determined by C. A. Reeds and E. Antevs, working independently.

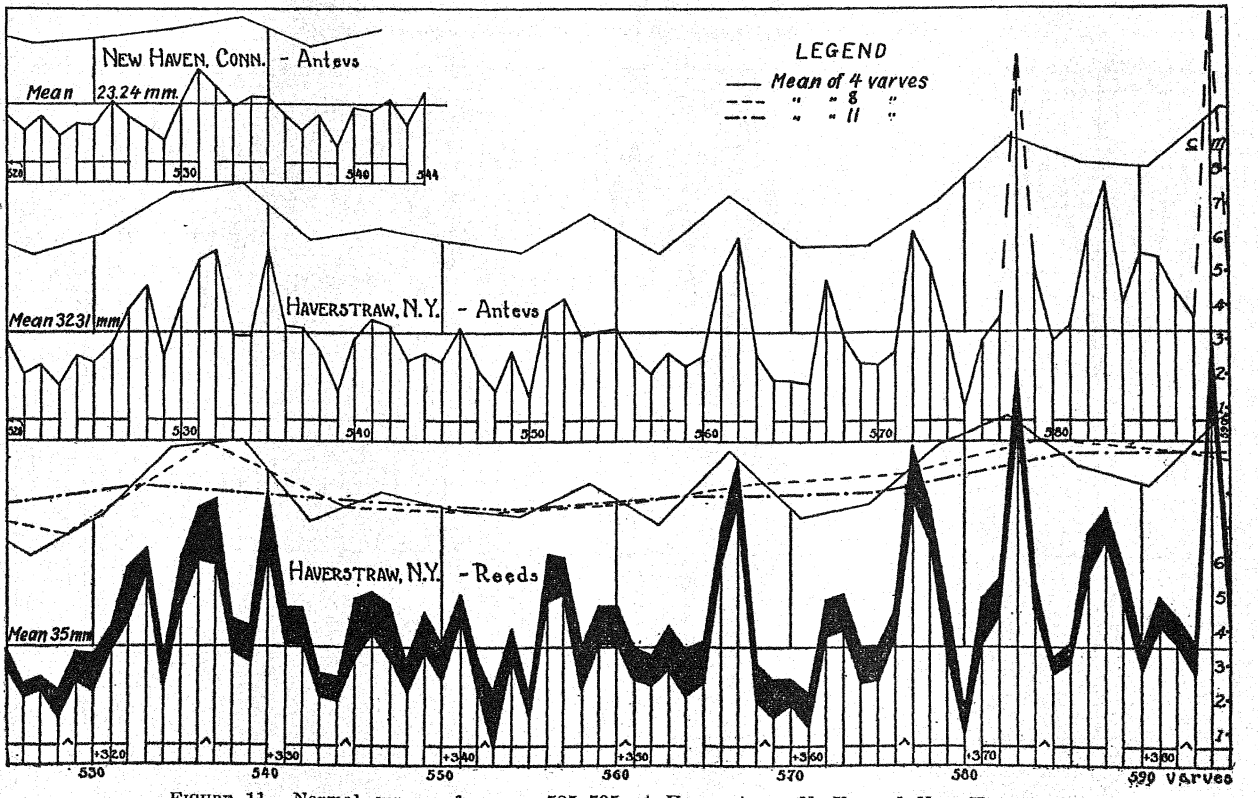



FIGURE 11.—Normal curves of varves 525–595 at Harverstraw, N. Y., and New Haven, Conn. As determined by C. A. Reeds and E. Antevs, working independently.

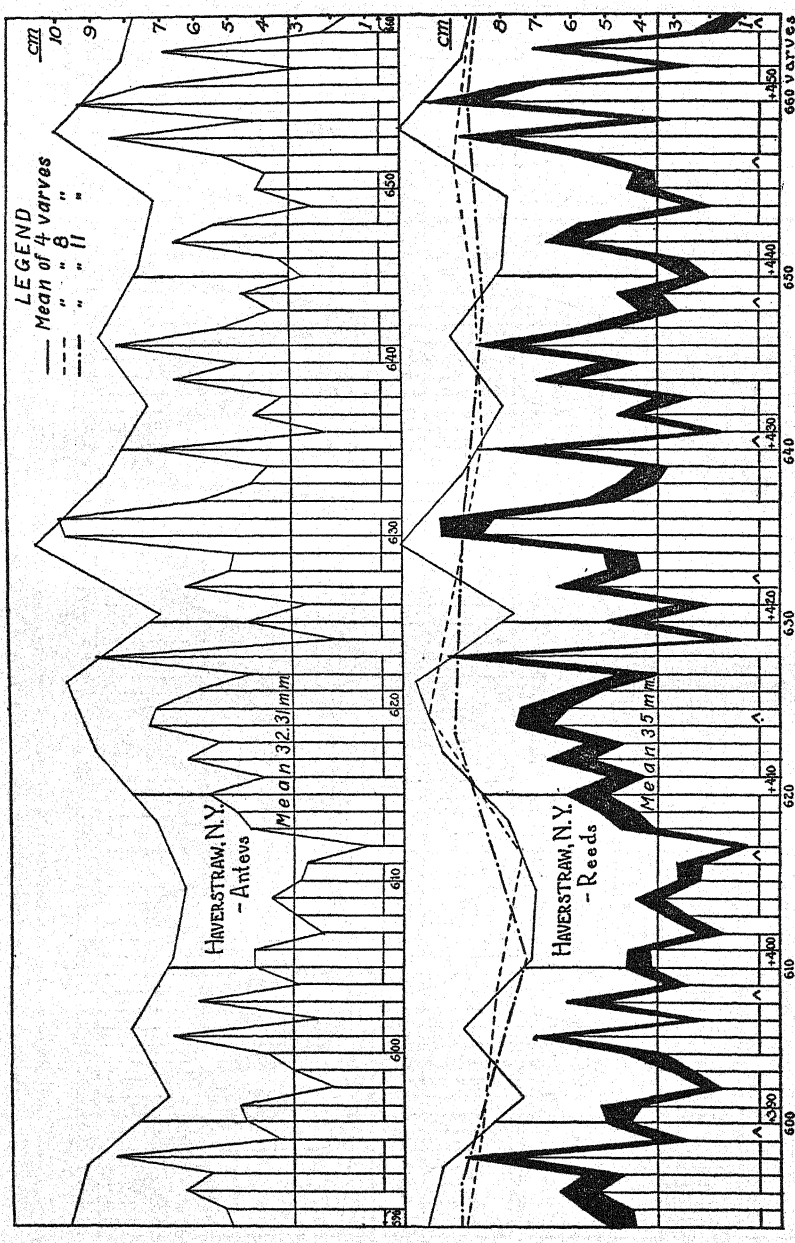



FIGURE 12.—Normal curves of varves 595–665 at Haverstraw, N. Y.
As determined by C. A. Reeds and E. Antevs, working independently.

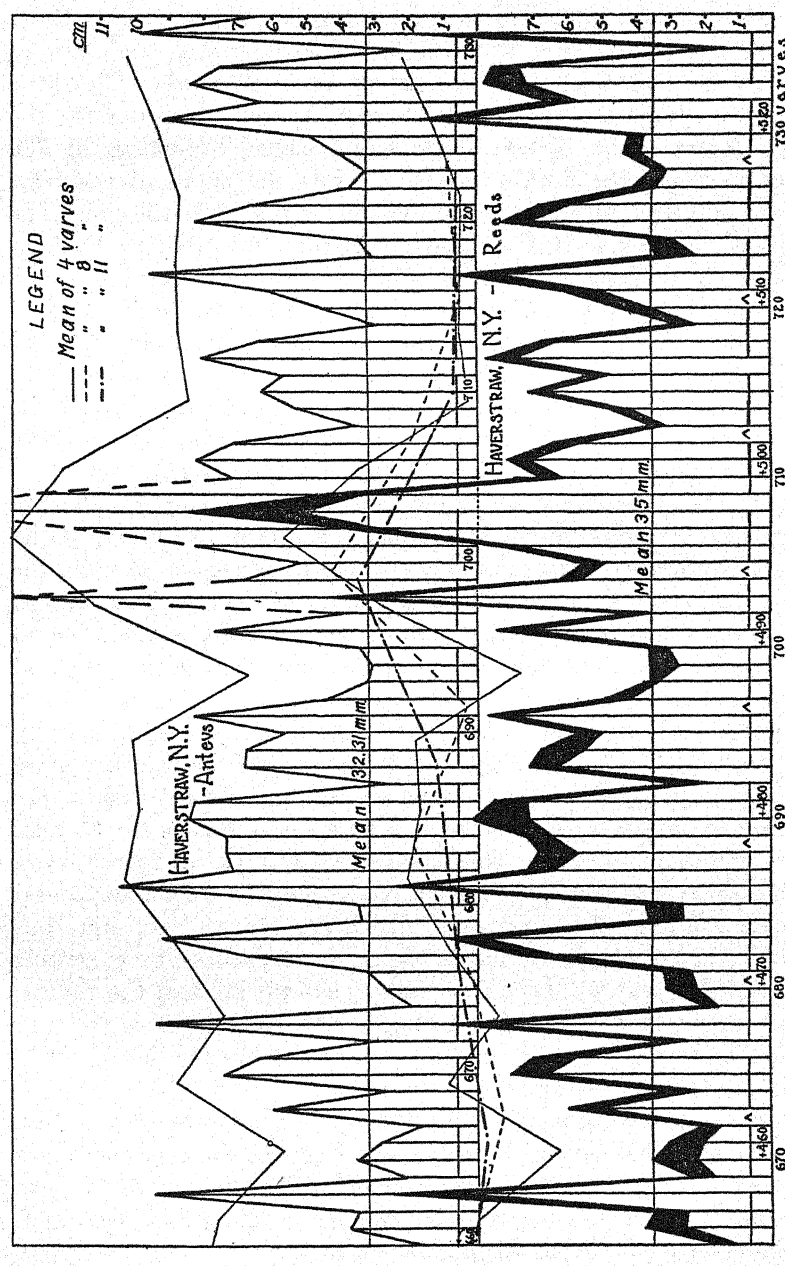



FIGURE 13.—Normal curves of varves 665–737 at Haverstraw, N. Y. As determined by C. A. Reeds and E. Antevs, working independently.

suggested correlation with the more prominent short-cycle variations of weather and solar radiation as noted by Clayton (1923).

To form a "normal curve" for the entire series of varved clays at Haverstraw, the five partial sections shown on Figure 2 and those from other similar sheets were averaged and drawn as one curve to form the Reeds graph represented in the lower portion of Figures 3 to 13. The Reeds curve is characterized by dark shading for the winter layers. The Antevs Haverstraw curve, consisting of 732 varves, occupies the middle position, while the curve of the New Haven sediments, representing 343 varves, is placed at the top. The varves as represented in the three curves correlate closely. Each of these curves represents the mean of the varve measurements taken in different clay pits. They are thus "normal curves." Antevs' curves have been developed from measurements taken in the field usually from three to five sections, while the data for Reeds' curve have been taken from field samples preserved in metal trays. The normal number of parallel sections used by Reeds was 5, but in some portions of his curve as many as 14 sections were averaged.

When the Haverstraw and New Haven varved clay graphs are compared they agree closely in contour. The mean, however, of the Reeds Haverstraw curve shows an average thickness of 35 mm., the Antevs Haverstraw curve 32.31 mm., and the Antevs New Haven curve 23.24 mm. These graphs show, furthermore, a variation in the thickness of sediments in groups of 3, 4, or 5 years, with occasional larger and smaller groups. This group arrangement suggests a correlation with the weather and solar radiation changes as noted by Clayton (1923). Accordingly, the mean of each four consecutive varves, in each curve, has been taken and set above the normal curve by using the mean of each curve as a base line—that is, the 35 mm. line in the Reeds curve. The consecutive groups of four varves, which were averaged in this manner, have been joined by a horizontal line near the base of each graph. The Reeds Haverstraw curve has been further smoothed by taking the mean of each two consecutive groups of four varves—that is, 8 varves, as indicated on the charts; also of every 11 varves. According to Clayton, the 8 or 11 year curves give some idea as to what the sun-spot curve for this 736-year period might have been like.

These smoothed curves show not only the more prominent group fluctuations in the deposition of the clay, but also those minor stages in the melting of the retreating ice fields. When the curve is above the mean, it indicates a period of more active melting and deposition and the reverse conditions when it is below.

In Figure 14 the smoothed curve, derived from Reeds' normal curve by taking the mean of each successive group of four varves,

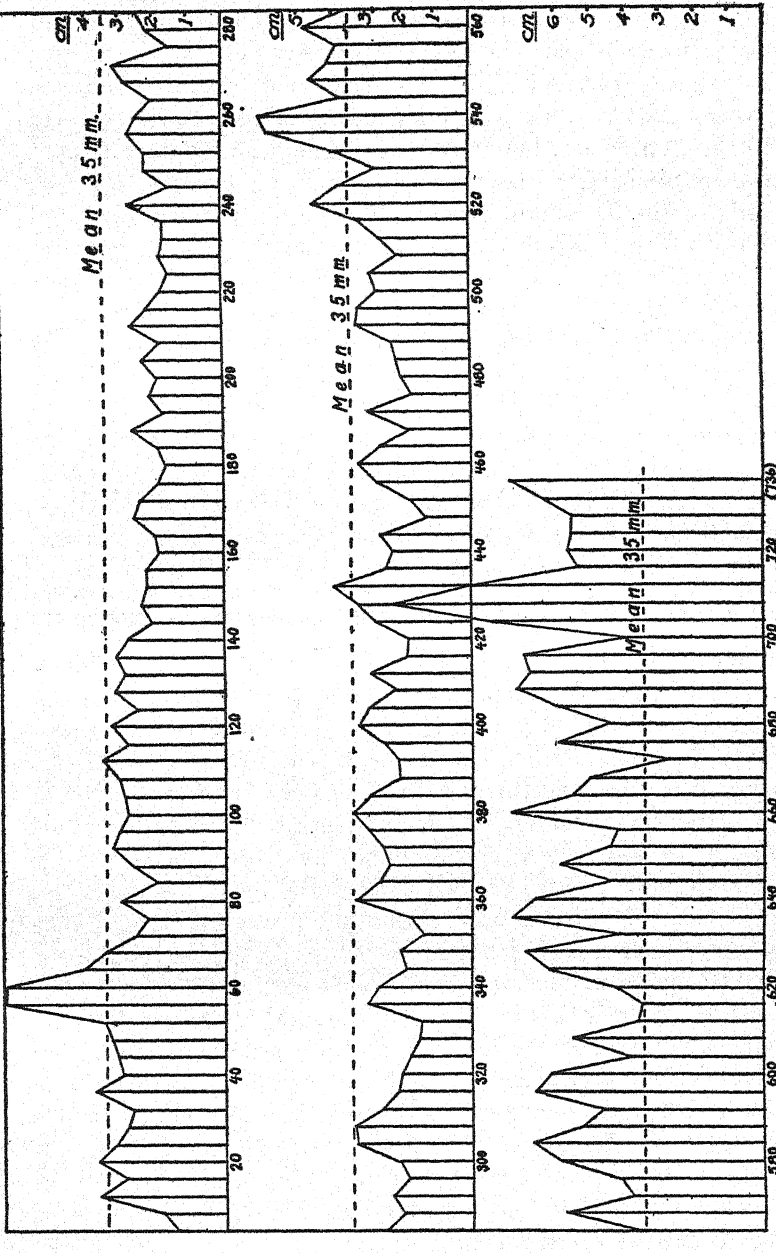



FIGURE 14.—Diagram of a smoothed curve

This smoothed curve represents the mean of each successive group of four varves at Haverstraw, N. Y., as entered on vertical spacings one-half of a centimeter apart. The mean for the entire series of 736 varves is 35 millimeters. Original drawing reduced. By J. A. Reeds.

has been arranged on the graph spacing used in Figures 2 to 13. This arrangement permits the entire smoothed curve of 736 varves to be placed on one sheet. The annual varves do not appear. It also affords an opportunity to see at a glance the more prominent major fluctuations and periodicities in the melting of the ice. Regular cycles are not apparent. The first prominent warm period was for the years 52–68. This was followed by a comparatively cold period to the 112th year, but it was not as cold as during the next 192 years, terminating with varve 300. For eight years, 300–308, the melting of the ice almost reached the normal between cold and warm temperatures. From 308 to 332 the curve moves gradually downward, indicating a 24-year period when the successive summers were progressively colder. Then, during the next 204 years, there follows a series of short cycles of warm and cold periods of varying length, which were for the most part below normal, terminating with 528 years. Then, curiously enough, the last 208 years, 528 to 736, were cyclic in form, but predominantly warm—that is, above the normal or mean line. When an opportunity has arisen to check varves 52 to 68 and 700 to 716 with varves from other localities, then we shall know whether these abnormal fluctuations were caused by excessively warm periods or were accentuated by local causes.

## PERIODICITIES IN VARVE CLAY GRAPHS AND TELECONNECTIONS

Periodicities in varve graphs have been noted by W. Köppen (1928), C. E. P. Brooks (1928), and E. Antevs (1929). Köppen recognized periods of 2, 3, 4, 5, 6, 7, and 8 years in North American varves, with the period of 2, 3, 4, and 5 years being frequent. Brooks has analyzed the teleconnections of De Geer between Sweden, North America, Argentina, and India. In Argentina he notes cycles of 5.1, 10.4, and 51 years in a curve secured by Doctor Caldenius at Lago Corintos, which was described and figured by De Geer (1927). The period of 10.4 years noted by Brooks approaches the 11-year sun-spot curve in length, but not in rhythm. In fact, Brooks comments on the almost entire absence of an 11-year periodicity in the varved clays. Antevs states that while stadial moraines indicate the periodical retreat of the ice edge and are especially suited for long-range periodic phenomena, the clays enable us to determine the exact length and character of the periods. The varve graphs are best suited for the study of short cycles. He regards the almost complete absence of the 11-year cycle in the curves studied by Brooks as being perhaps the most important result so far obtained from the analyses of varve curves.

Brooks (1928), in discussing De Geer's (1926) teleconnections between Zealand (Denmark) and the Little Ferry, N. J., clays of the Hackensack Valley, which were described and diagramed by

Reeds (1926), calls attention to two correlation coefficients, one of +35, which suggests that the teleconnections appear to be undeniable; the other of +24, which shows that nearly half the apparent connections are due to a 2-year periodicity common to both. Brooks makes further comments, but it does not seem desirable to feature them, since De Geer's correlations, in this instance are premature and misleading. Reeds informed De Geer of this fact in August, 1927.

On Plate II (1) De Geer attempts to correlate: (1) The Swedish curve, years 5540 to 5629, with portions of Reeds' Hackensack curve and Antevs' Connecticut Valley curve; (2) through years 5629 to 5684 he arranges the Hackensack and Connecticut Valley curves in juxtaposition; (3) for years 5666 to 5892 he places Hackensack varves opposite Scanian (southern Swedish) varves; (4) for years 5736 to 5869 he diagrams varves from Dutchess Junction, N. Y., opposite those from Hackensack and Scania.

The objections to the aforementioned teleconnections are as follows:

A. The agreement between the various graphs is apparently not close enough to suggest a correlation.

B. The direction of ice retreat from the terminal moraine on Staten Island and Long Island was northward up the Hackensack, Hudson, Connecticut, and smaller river valleys. As the ice border, which extended in a general east-west direction, retreated northward at a rate somewhat less than 100 feet per year, clays were deposited in marginal glacial lakes in the separate river basins. The Hackensack Valley clays at Little Ferry, N. J., are the southernmost exposures and consequently the oldest known in eastern North America. Twenty-five miles to the north of Little Ferry, and in direct line of retreat of the ice, is Haverstraw, N. Y., with the oldest clays appearing in the Hudson River Basin. The Hackensack and Hudson River Basins, although parallel for nearly 50 miles, are separated by the Palisade Ridge and Verdriderger Hook. Fifteen miles to the north of Haverstraw, in direct line of retreat of the ice and on the north side of the Highlands of the Hudson, is Dutchess Junction, N. Y.

C. Antevs (1928) has definitely correlated the Haverstraw clays with those in the Quinnipiac River Basin at New Haven, Conn. Likewise, he correlates the Dutchess Junction clays with Hartford, Conn., clays. The 2,500 varves in the Hackensack clays, being older than the Haverstraw clays, are not considered in the correlations which Antevs has established between Connecticut localities and the Hudson River Valley.

D. The geographical position of the localities in New Jersey, New York, and Connecticut with reference to ice retreat and deposition, as well as the correlations which Antevs has established in eastern

North America, render De Geer's correlation of Hackensack clays with Dutchess Junction and Connecticut Valley clays as premature and misleading. It will be necessary for Brooks to revise his coefficients of correlation again when the teleconnections between Sweden and eastern North America have been established.

## SUGGESTED CORRELATION OF SOLAR RADIATION, WEATHER, AND VARVED CLAY VARIATIONS

It has been stated that the character of the weather during the melting period of the ice varied from year to year, and that these fluctuations are reflected in the varying thickness of the annual deposits (Bruckner, 1921; Osborn and Reeds, 1922; Sauramo, 1929). After calling attention to wide range correlations or teleconnections between Sweden, North America, Argentina, and northwestern Himalayas, in which more than 80 per cent of the varves are said to agree, De Geer (1927) states:

> This remarkable coincidence of such rapid variations at such considerable distances, caused by simultaneous ice melting, seems not to be explicable in any other way than by variations in the amount of heat from the sun.

De Geer (1926) states that the rate of melting depends almost entirely on the intensity of solar radiation. In those temperate regions which were glaciated during the Pleistocene epoch he considers that practically all of the solar radiation was spent in melting the accumulated snow and ice, while now, after the yearly snow and ice is melted, the balance is available for warming the ground. During the retreat of the ice he notes that the changes in solar radiation correspond fairly well with the changing amount of melting water. Since this water found its way to the ice edge, he considers that the amount of reassorted morainic material eroded and carried away by the subglacial rivers varied very nearly at the same rate as the amount of melting water. Furthermore, by getting accurate measurements of the annual amount of the finest and most regularly deposited sediment from such waters (varved clays), he considers it would be about the same as getting readings from a gigantic natural self-registering thermograph. Brooks (1928) suggests solarigraph for thermograph.

A comparison of Figure 1 with Figures 2 to 13 shows that the solar radiation variations, when plotted in the same manner, are not different in kind from those of the varved clays. In fact, it is surprising how close the solar fluctuations simulate those of the varved clays. No direct comparison can be made between them, since the years represented in Figures 1 and 2 to 13 are not contemporaneous. The close agreement in the form of the graphs, however, leads one to offer a tentative correlation of the annual solar radiation variations with those of the varved clays. Clayton has

shown that there is a real relation between solar radiation variations and weather changes; and, since weather affects the conditioning of glaciers and is reflected in the varve graphs shown herewith,

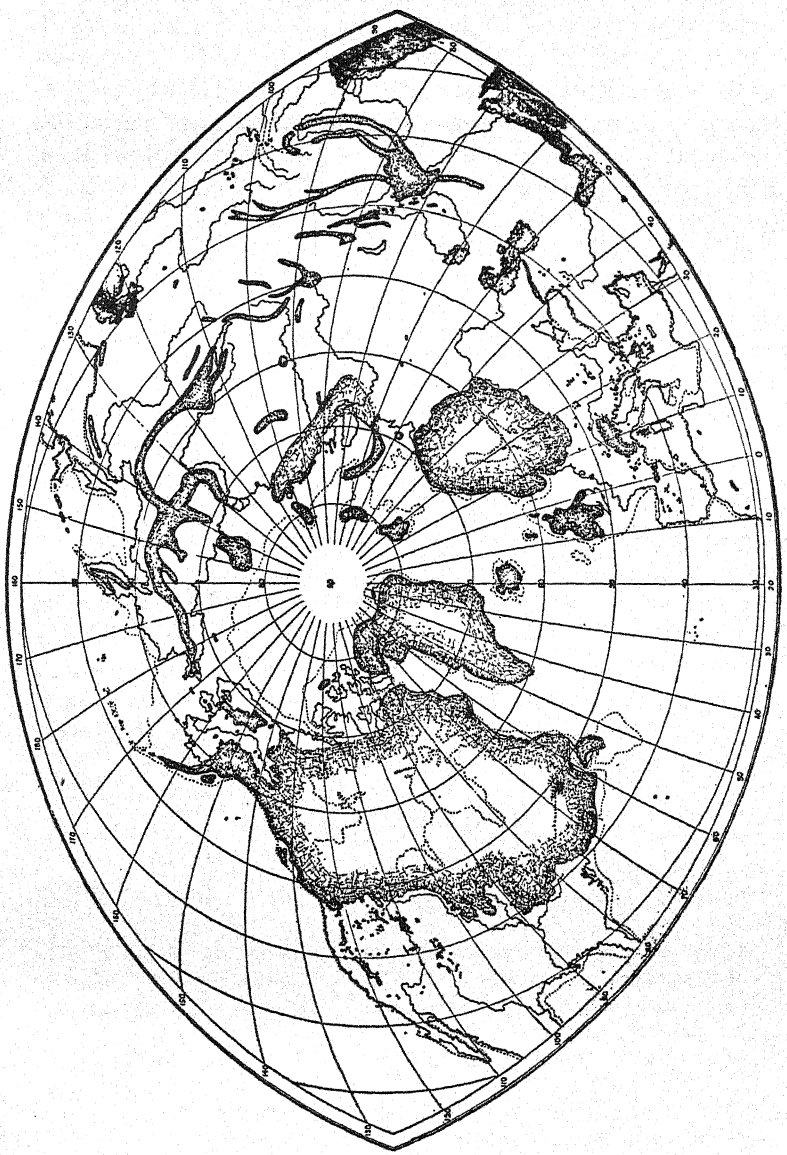


FIGURE 15.—Northern Hemisphere
North America and northern Europe: Areas glaciated during the last glaciation. Asia and mountains in Europe and America: Areas glaciated at one time or another during the Pleistocene. Lambert's equal area projection.
(After Antevs.)

a suggested correlation of solar radiation weather and varved clay variations is here proposed.

## CONCLUSION

It may be stated that weather, as distinguished from climate, affects the conditions of ice masses daily, seasonally, annually, and

in groups of years of varying length. Glaciers are conditioned by opposing factors, nourishment, and depletion. These, in turn, are governed by changes in the weather and in the amount of solar heat. The intensity of solar radiation reaching the earth is affected by the amount of water vapor, carbon dioxide, ozone, and dust in the air; also by irregular variations in the sun itself. The variations in the sun fluctuate slightly about a mean of 1.938 calories per minute per square centimeter. Although these solar variations are moderate, they are important, for a real relation between them and weather changes, as well as glacial conditions on the earth, is strongly suggested. The records preserved in living and fossil trees and varved glacial clays show not only seasonal and annual variations, but also fluctuations for irregular groups of years, which seem difficult to explain on any other grounds than a real relation between them and the changes in weather and solar radiation.

The graphs of solar constant and varved clay variations appearing in this paper show that they are not unlike; in fact, they bear close resemblances. Short cycles, averaging four years in length, are prominent, as shown by the smoothed curves. Longer periods as noted in Figure 14 are not wanting.

A special study of Haverstraw and New Haven varved clays of the last glaciation (fig. 15) shows that their fluctuations in thickness were due not to local causes, but to primary factors embracing a strict periodicity in the melting of the ice, summer by summer. The fact that these fluctuations vary from year to year, and for short as well as for long irregular cycles, shows that these variations were governed by changes in the weather and solar radiation extending over a period of more than seven and one-third centuries.

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# WILD LIFE[1] PROTECTION—AN URGENT PROBLEM

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[With 4 plates]

When the white man first reached America he found a country generally abounding in big game, upland birds, waterfowl, fur bearers, fish, turtles, and frogs, which could be used as food or in other ways. It was necessary for him to utilize these and he did so with profit to himself. In his settlement of the country, he destroyed the forests, plowed the prairies, drained the swamps, grazed his stock on the hills to the injury of the forage, and generally greatly depleted the wild stock and restricted the areas available to the wild forms that first made his existence on the continent possible. The condition is essentially the same throughout the world wherever man has settled. Now, man's greatly increased progeny still has the desire for the wild life or its products, but some forms have been exterminated and nearly all have been so far reduced that the supply is far short of the demand. Some people value animal life for itself, others for the recreation of taking it, others for the profit to be derived from it, and others for the beauty or usefulness of its products.

Some of the depletion and restriction of the habitats has been inevitable, but much has been the result of thoughtlessness and a disregard for the future and can be remedied. The so-called "development of natural resources" has all too often consisted of taking what nature has supplied without providing for a continuance of the resource. It has been little less than exploiting or looting and was never development in a true sense. The time has now arrived when real development work must be carried out if our wild life resources are to be perpetuated in such quantities as to be of material value and benefit to us.

Not only the United States and its possessions but the remainder of the world has large tracts of so-called "waste land" well adapted to raising different kinds of wild life that are needed by mankind

[1] The term "wild life" as herein used refers to all forms of wild vertebrates.

but which are now producing little or nothing. Many lands that may require 50 years to grow a crop of timber can, during that period, produce annual crops of fur and game with no detriment to the growing timber; and some of the abandoned farm lands are probably better adapted to raising profitable crops of wild life than they ever were to domestic crops.

Proper administration can greatly increase our yield of wild life and place the various species on a secure constant production basis instead of the precarious existence many of them now experience. Financial or recreational values can be restored where little or none have existed since the time when man depleted or destroyed the original stock.

We are supposedly living in a machine age, and we utilize machinery whenever possible. We should therefore utilize animal life to convert vegetation into more valuable products, for such animals as beavers and deer convert surplus vegetation into fur or meat, while the carnivores accomplish the same result by eating animals that have already converted vegetation into meat.

To produce such crops, however, in paying quantities will require the application of wild-animal husbandry, just as good management is necessary in domestic livestock raising.

American principles of wild life protection are based upon the premise that the wild life of the country is the property of the people, represented by the Government, and the individual has no title in it except as he subjects the wild life to possession in accordance with laws or regulations or in the absence of any prohibition against the taking. The landowner has no right to the life merely because it occurs on his land. He may take it there only under the general conditions prescribed, which usually apply to landowner and nonlandowner alike. The landowner may prevent others from taking the animals on his land only by preventing trespassing. On the public domain, that is, land owned by the Federal, State, or county governments, permission to take animals is usually granted to all who obtain licenses or can qualify as to residence or citizenship requirements when such are required. This almost invariably results in the taking of more animals than should be killed if the stock is to be maintained.

The system does not encourage the individual to leave wild life to breed in order that the supply may be increased, for there is no assurance that he who exercises moderation in his killing will profit by his discretion. On the contrary, the next hunter, trapper, or fisherman may take an unreasonable number, even within legal limits, and kill the very animals that the first man has left as breeding stock. This system seems to have been modeled upon the saying "A bird in the hand is worth two in the bush." If our

wild life is to be saved, we have the option of giving it more complete protection or of abandoning the principle that any one who qualifies as to license, citizenship, or residence requirements may engage in taking it. In other words, we have before us the imminent prospect of practical extermination of those forms of wild life commonly taken by mankind, unless we adopt stringent enforcement of laws and regulations for their protection or give the landowner control of wild life on his lands. In the latter event the man who does not own land will have no place to hunt, trap, or fish unless he obtains the privilege from the landowner.

A few people realize the reasons for the depletion of wild life and know that in many instances proper wild-life administration will restore interesting and valuable forms, but the greater number do not know that conditions can be remedied, and they accept the exhaustion of the natural resources as inevitable.

The idea expressed by one concern selling fur-bearing animal stock that "fur wearers are breeding faster than fur bearers" can well be applied to all kinds of wild animals used by man. As no adequate substitutes have been found for the animals themselves and many of their products, and as we have not reached the stage of checking the rate of increase in human demand, the only remedy apparent is to increase the wild life.

This indicates a very definite field for the student of wild life, for he is the only one qualified to determine the true relative value of the various forms of wild life and to advise legislative bodies, game protective organizations, and the public in general as to their value and the proper steps that should be taken to perpetuate the animals and assure the maximum returns.

The array of forms that have been exterminated locally or entirely, or that have been seriously depleted, is generally better known to scientific men than to any other group, and they are in the best position to show the values of such life. With the various means of the present time for presenting information—through the daily press, magazines, special circulars, motion pictures, the radio, and personal lectures—the scientific man has ample facilities for reaching the public.

The public is glad to receive authoritative information from the scientific man provided the material is presented so that it can readily be understood. Legislative bodies and game protective organizations also appreciate his assistance and advice.

The almost universal interest in animal life and its behavior as shown by the regularity with which hunting, fishing, or discussion of animal actions arises in gatherings of men free to discuss varied subjects augurs well for the success of a program to gain the interest and support of the public in the movement for wild-life upbuilding.

The harmonizing of the various interests and the development of well defined programs for wild-life administration requires the broad and technical training of naturalists. They alone are in a position to anticipate the far-reaching results of protection or control measures. Furthermore, because of their interest in the wild life they should be the leaders in its proper development and administration. The field of technical advisors to wild-life administrators is a large one and as yet practically untouched. From the wildest and most remote tracts in the world to small city parks, there are problems relating to wild-life administration and it is doubtful if there is in existence to-day an organization administering wild-life protection that does not have numerous unsolved problems of a biological nature that are handicapping its work.

Successful protection of the wild life of any region or country is primarily contingent upon the development of an attitude on the part of a majority of the people favorable to wild-life perpetuation. Protection is necessarily based upon public sentiment, well drafted laws, and their vigorous and impartial enforcement. To obtain either the enactment of good laws or their successful enforcement it is necessary that the masses of the public realize that it is to their benefit to protect wild life. This points out the great importance of developing methods of showing the value of wild life, means to employ for its preservation and the benefits to be derived from protection.

Heretofore, the sportsmen or a very few foresighted and courageous lovers of wild life have led minority fights for its protection. Some of these fights have ultimately been successful and have accomplished great good, but they have been hard struggles and the burden has been heavy on the few who were working for the general benefit. Many good causes have failed and most of those that have succeeded have been limited in scope to the lines in which the sponsors were most interested. As might be expected, the result of various groups of diverse interests taking up the matter of protection of the objects of their particular interest has produced inconsistent local legislation, usually designed for the protection of one group of wild life, often at the expense of another, which in some instances has been of equal value.

In keeping with the development of the legislation, the enforcement of the laws has frequently been spasmodic and inconsistent and often in the hands of those interested in particular kinds of game, fur, or fish rather than wild life as a whole, which has resulted harmfully in some instances. With a few outstanding exceptions we have had no consistent wild-life administration programs. That is, but few regions have developed really consistent and properly balanced wild-life laws and enforcement calculated to develop the maxi-

mum benefits from all forms of wild life that might be produced on the lands or in their waters.

The relative values of the various kinds of wild life have not ordinarily been carefully considered. If the dominant group was interested in upland game birds or waterfowl these forms were usually given fair protection and other forms of life ignored, while such interesting and valuable fur bearers as raccoons, skunks, and minks were termed vermin and campaigns of extermination waged against them. If big game was the principal object of concern, other forms were neglected.

As the scientific man observes the policies and work of the game administrators, his frank, unprejudiced commendation as well as criticism will be of value and will encourage adherence to sound policies. The custom of human nature to be silent when matters are satisfactory and to speak only when displeased often makes it difficult for public officials to adhere to the course that is best for the greatest number of people. While the masses are satisfied and silent the selfish interests are criticising, and attacking, and exerting every effort to gain their ends. More frequent expressions of approbation might assist the officials in following the correct path.

Wild-animal husbandry is a field almost as novel as the term itself and offers problems comparable to those being worked out by stock raisers and farmers who are assisted by technical advisors and experiment stations. As a whole, the basic problem is that of obtaining the maximum continuous production under wild conditions.

The relatively new industry of fur farming shows that animals at one time scarcely considered can be raised at a profit. The production of wild animals might be compared with the ranging of cattle, sheep, and horses on the western stock ranges of the United States. As tracts are inclosed a more intensive and better controlled production can be obtained, which would be comparable to some of the modern fur farms. Figuratively speaking, the minks and martens may play about the feet of the deer in the forests, while young muskrats and baby ducks romp in the marshy edge of the lake and watch the fish jumping in deeper water.

In addition to the general work needed by the county, State, and Federal agencies concerned with wild-life protection, there is a field for the biologist conservationist (bio-conservationist) in assisting clubs and landowners to make their tracts yield properly. Such positions may be termed consulting naturalists or technical wild-life advisors.

There are innumerable wild-life administration problems to be solved. Among the outstanding of these are the determination of the maximum numbers of various species that can be produced on

areas of various types, and the combinations of animal life on various areas that will yield the maximum returns either in money, or pleasure, without detriment to other interests.

The raising of more than one kind of crop at a time on land is very appealing to the agriculturist, and in wild-animal husbandry this practice is particularly applicable. For example a tract while growing timber on the uplands can produce beavers and mink in the streams and bonds, raccoons and opossums will roam the entire area with the foxes and deer, and some fish can be raised in the streams and ponds in excess of those killed by the minks, while frogs and turtles may supplement the yield.

The working out of methods by which the carrying capacity of areas may be determined is an important problem that has a wide application. Excellent progress has been made in determining how many sheep or cattle should be grazed on various types of stock ranges and much good has resulted from application of the knowledge obtained. Similar need exists for yardsticks by which we can ascertain how many deer or elk can be produced on a given tract or how many beavers or muskrats, or both, can be raised on various lakes and streams, and how many fish can be raised in such waters at the same time. How many raccoons, mink, otters, turtles, and frogs can be produced on a given swamp? Could greater revenue be derived by raising waterfowl, or should a compromise be aimed at and a combined harvest of fish, turtles, frogs, fur bearers, and birds be sought? What kinds of stock should be placed on a tract and how many of each kind?

In line with the teaching of the proper times and methods of taking wild life is the teaching of proper methods of preserving animals or animal products for use or for the market. Ignorance and neglect of the best methods of preparing the pelts of fur bearers annually costs the trappers a surprising sum. Waste of game meat and other products should be unheard of in the present day but it occurs regularly among sportsmen who apparently do not inform themselves how to care for game and by aborigines and some others who regularly live upon game. The prohibition against commercialization of parts of game animals has resulted in the waste of many fine skins and heads of such animals killed for food purposes. Certainly no provision should be advocated which will stimulate greater killing of valuable forms where the supply is already inadequate, but thought can well be devoted to devising means of permitting the utilization of all parts of the animals that are lawfully killed.

Determining the proper proportions on the range of the sexes of polygamous game animals such as deer and elk is a problem that has a direct bearing on the formulation of laws and regulations for the protection of these animals.

Presentations of the cash values of wild life produced on given areas well stocked as compared with the revenue from the same areas or similar tracts poorly stocked or producing farm crops of limited value often can be used with convincing effect. This can be strikingly shown by assembling such figures as are available of game mammals, birds, fur bearers, frogs, turtles, or fish that have been taken from known areas such as islands, lakes, counties, or States and multiplying the number by the present values of such animals. In many cases it will show that the wild stock that can be produced on the area is far more valuable than the domestic products now being raised.

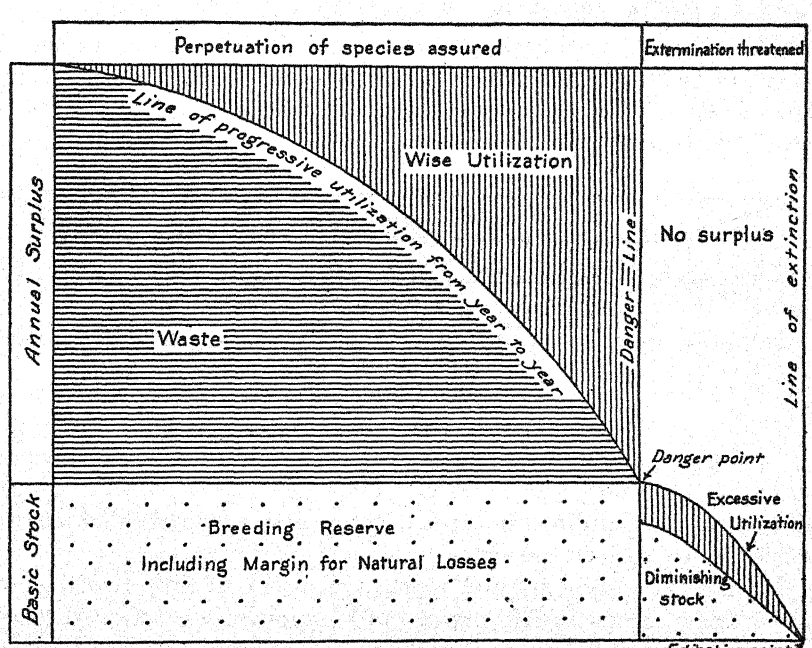



FIGURE 1

In an effort to show diagrammatically or graphically the progressive utilization and extermination of a species,[2] the design shown in Figure 1 has been developed. It is an attempt to enable one to visualize what to-day is probably the greatest problem with which the wild-life administrator is confronted. It is based upon the fact that a given area of land or water or both can continuously support only a certain maximum number of breeding animals and their progeny until the reproductive stage of such progeny is reached. There are, of course, innumerable factors that affect this condition, but the

[2] This and certain other diagrams and extracts herein are taken from the author's paper Getting Public Support for Mammal Protection published in the Journal of Mammalogy, vol. 9, No. 3, pp. 195–200, August, 1928.

basic principle is that an area can sustain up to and not beyond a certain abundance. If the stock is increased above the carrying capacity of the area its productive capacity is lessened, and this naturally leads to ultimate reduction of numbers. If the area is not fully stocked it will not produce as large a crop as it might under best utilization.

If more than the normal surplus produced by the basic breeding stock is taken, the breeding supply will be reduced and production can not be sustained. If all the surplus is not used it is not only wasted but it also becomes a source of danger through overstocking.

This is intended to make clear the fact that there is a definite critical point which, if passed in the case of any valuable animal or plant, leads to reduced production and threatened extermination.

It can be shown that by building up the wild stock a surplus can be provided that may be harvested at a profit, and indeed it must be removed to prevent overstocking. The work of the biologist is to

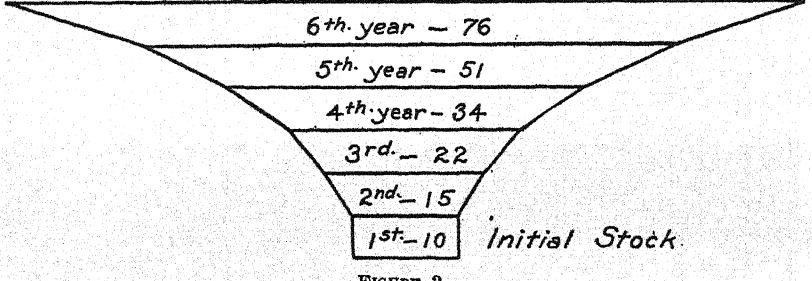



FIGURE 2

determine the dividing line which is not always clearly defined and varies as conditions change.

Reliable statistics applied to the graph in Figure 1 will show the trend of the wild life population. Appropriate action then becomes obvious.

The steps in increasing the wild-life supply may be graphically illustrated by the inverted pyramid.

The problem is one of arithmetical progression and by application of the proper figures appropriate to the species, region, and conditions of life it is possible to illustrate the case quite clearly. The method is applicable in illustrating the increase of injurious forms as well as beneficial ones.

With the foundation idea established of maintaining a definite maximum breeding stock and harvesting only the surplus, we next have for consideration factors that must guide us in harvesting the surplus. Different factors, of course, are operative in different animals.

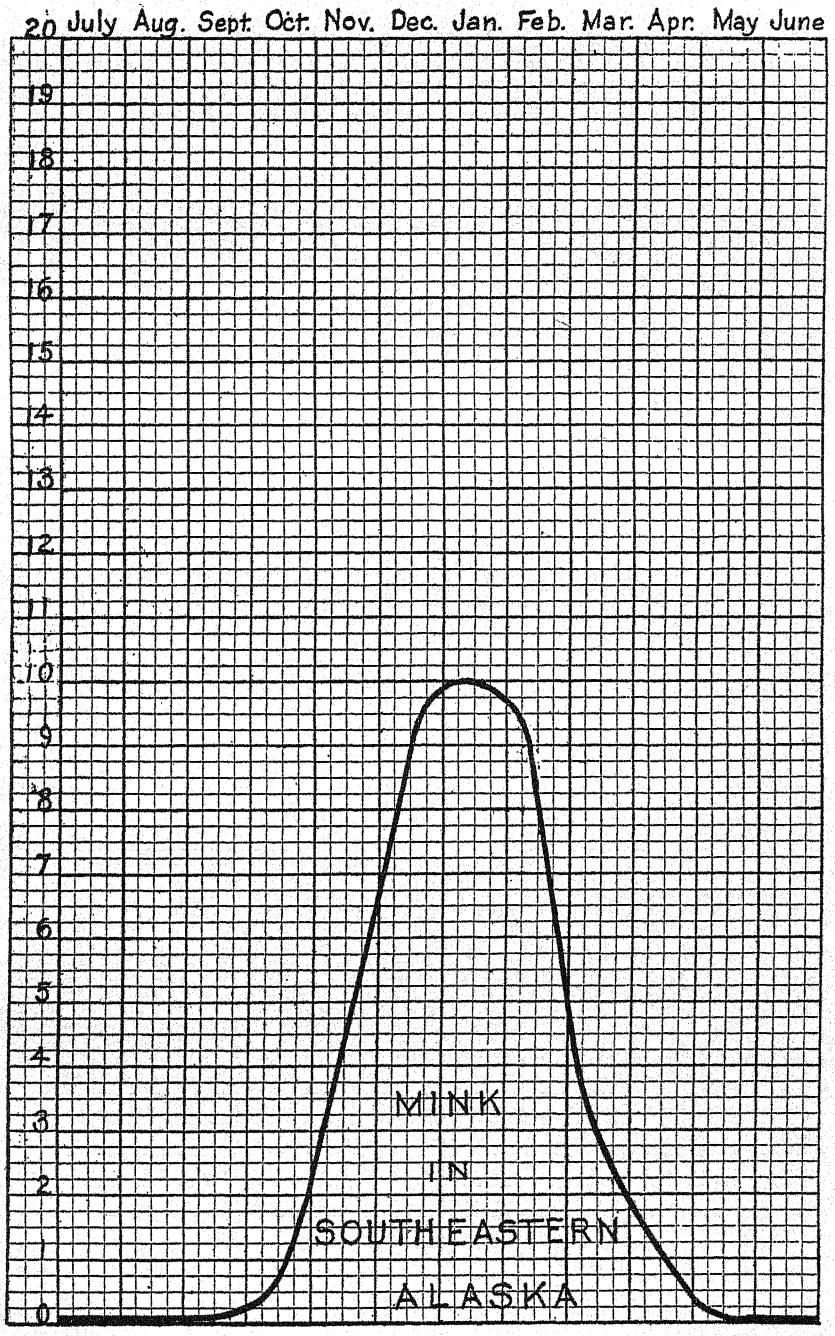

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FIGURE 3

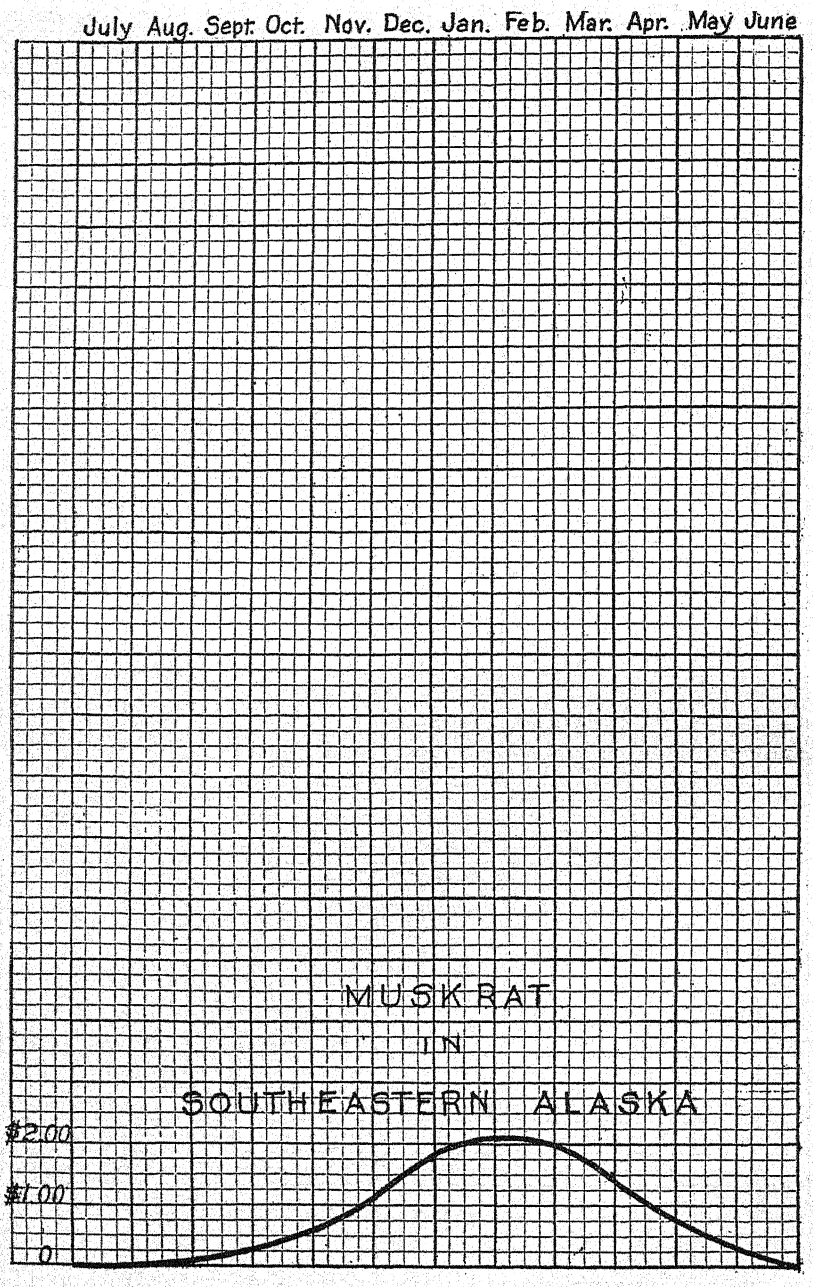

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FIGURE 4

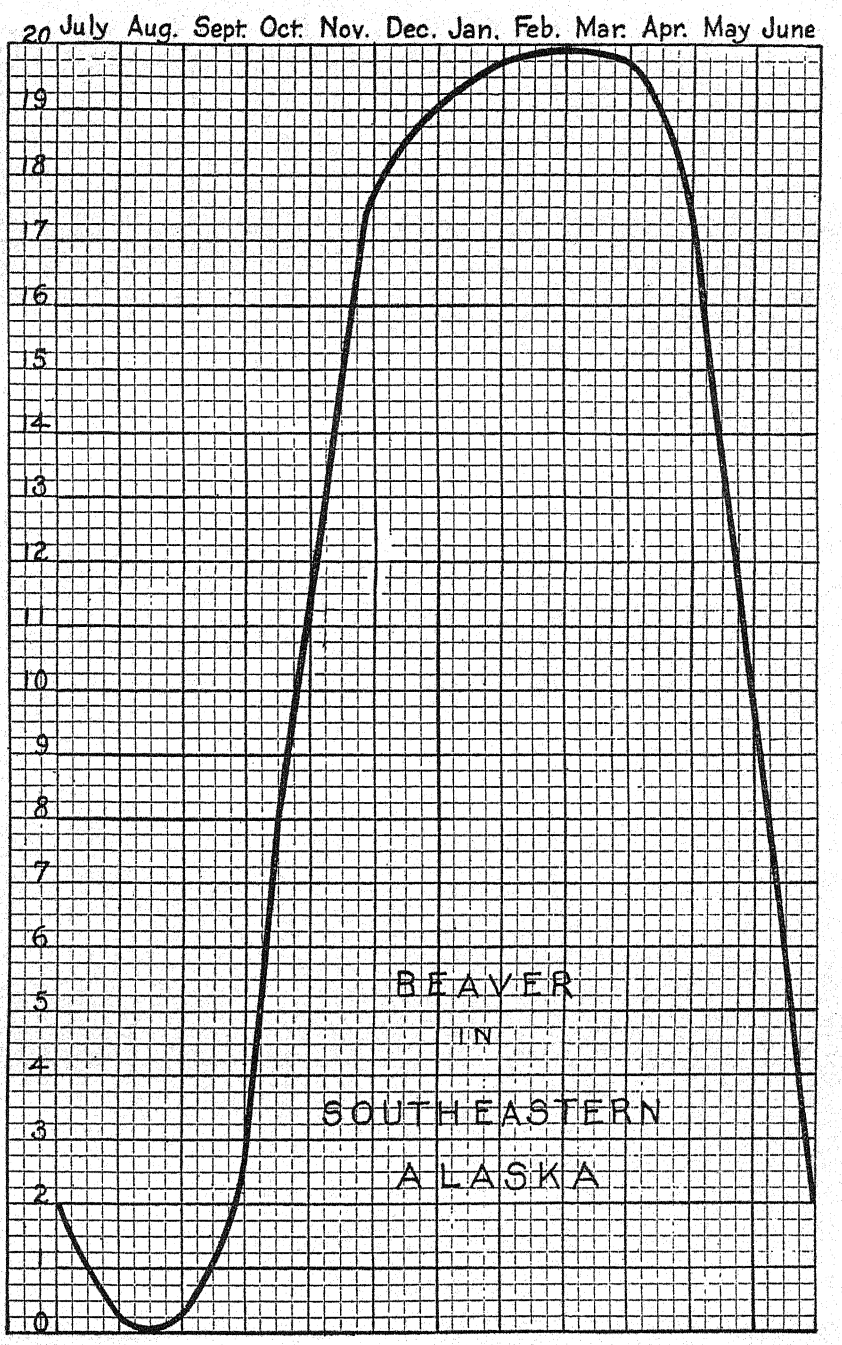

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FIGURE 5

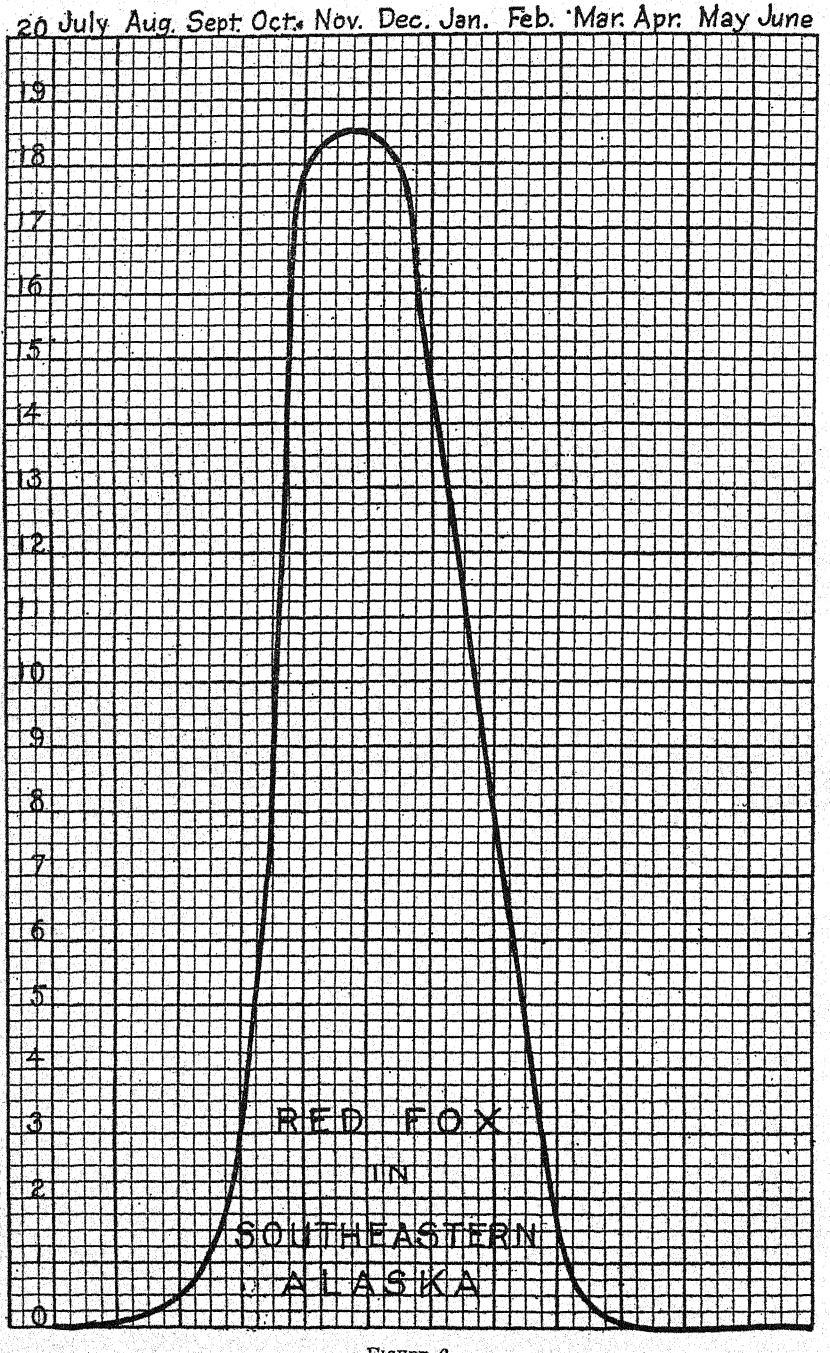
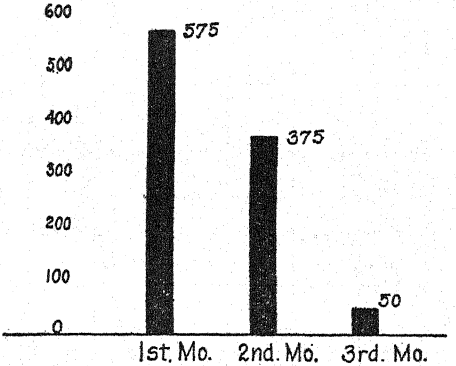

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SOUTHEASTERN
ALASKA

FIGURE 6

The land fur bearers are a group of mammals that are utilized in a rather uniform manner and are subject to certain fairly constant factors and the changes in the value of their skins in the course of a year can be shown graphically in what might be termed "The Cycle of the Fur." The graphs are not intended to be exact but rather to illustrate the underlying principle. They are based upon statistics of Alaska furs, supplemented by an intimate knowledge of fur conditions in the territory. They have also been modified to meet suggestions made by fur dealers and trappers. Each graph represents a general average for the various species in southeastern Alaska over a period of years, but can also represent equally well an individual fur bearer.

The practical application of these is obvious, namely to indicate the proper period for open seasons. It will be seen that the peaks of primeness do not coincide for all the animals. This clearly demonstrates the need for the fur seasons being adjusted for the various species if the maximum values are to be derived from the animals taken during open seasons. The next problem is to demonstrate to the public why it is good business to prevent encroachment on the breeding reserve; and if the stock has already been depleted it is even more important to indicate where use must be curtailed in order to restore the proper capital of breeding stock.



Approximate average monthly distribution of 1000 land fur bearers taken during a 3 months trapping season

FIGURE 7

To illustrate this, the fur bearers have again been drawn upon for an example. It is well known that in general the trapper takes the greatest portion of his total catch during the earlier part of the season; and that the daily catch declines as the end of the season approaches. This, of course, is due to the fact that there are more animals available for him at the opening of the season and that they are less wary and thus more easily taken. To illustrate this point and another still to be brought out, let us assume that on a given area 1,000 skins of a fur bearer might be taken during a 3-months' open season. The first month there would probably be 575 taken, the second month 375, and the third month 50.

In the example just given it has been indicated that 1,000 skins would be taken on the area. Let us assume, however, that the tak-

ing of this number of animals will not only consume the surplus but will also make inroads on the basic breeding stock or capital. Under these conditions a wise administration demands that the taking of part of this number be prevented. How can this be done and still satisfy the trapper, the manufacturer, and the consuming public? If the season be shortened a little at both ends, reducing it to two months, let us suppose that this will save 50 animals and that it will prevent encroaching on the breeding stock. It is a matter of surprise to many that the 950 animals taken in two months will be worth more than would be the 1,000 taken in three months.

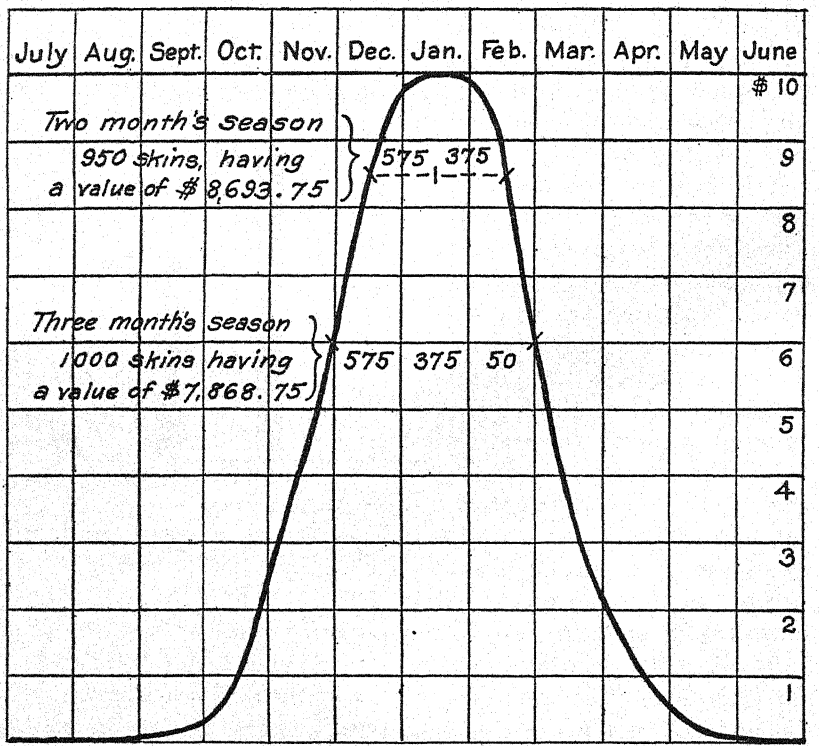



FIGURE 8

This may be illustrated by combining the graph showing pelt value by primeness with that showing the total fur taken by months. Of the 1,000 animals trapped, the 575 of the first month of the open season will be taken mainly before they are prime or in the best market condition; the 375 of the second month are the only ones taken within the period of their maximum value; and the 50 of the

third month are taken when their value has considerably declined. The value of this take would be about as follows:

| | |
|---|---|
| 575 animals at $7 | $4,025.00 |
| 375 animals at $8.25 | 3,468.75 |
| 50 animals at $7.50 | 375.00 |
| Total value of 1,000 skins | 7,868.75 |

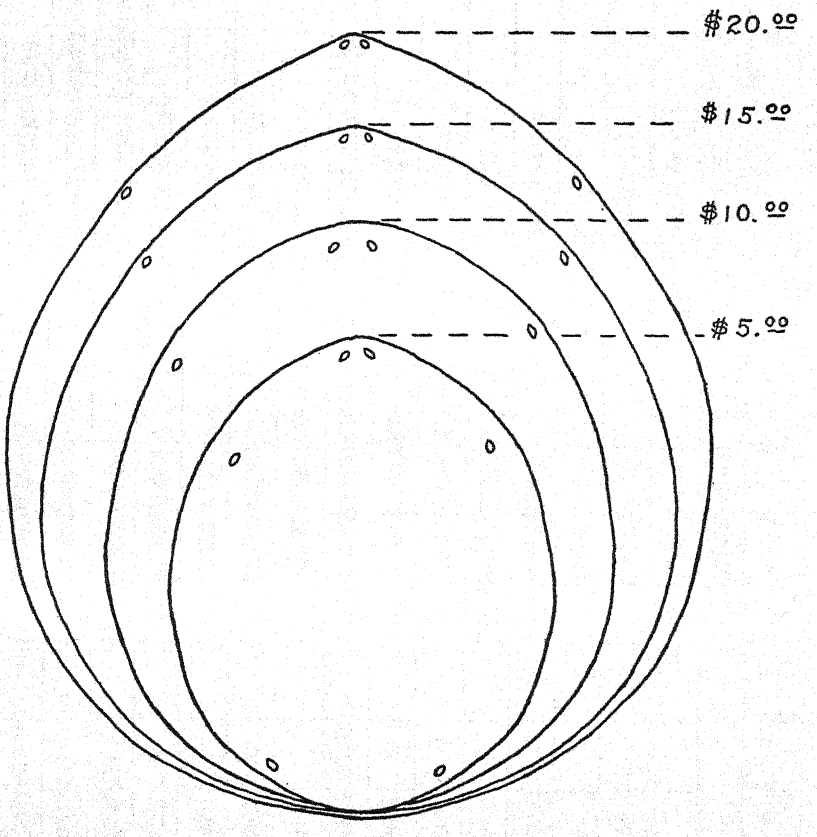



FIGURE 9.—Relative values of beaver skins of different sizes

On the other hand the two months' season allowing a take of 950 animals with fur in prime condition in practically all cases would produce:

| | |
|---|---|
| 575 skins at $9.25 | $5,318.75 |
| 375 skins at $9 | 3,375.00 |
| Total value of 950 skins | 8,693.75 |

Thus by taking 50 fewer animals in two months the actual receipts from the fur crop would be $825 more than would have been brought by the 1,000 animals taken over a period of three months.

In this way the two principal objects have been accomplished, namely saving the adequate breeding stock and increasing the profits.

Another means of enabling visualization of a problem in connection with the harvesting of the fur crop is the diagram on page 341 that shows the relative values of different sizes of beaver skins, otherwise alike.

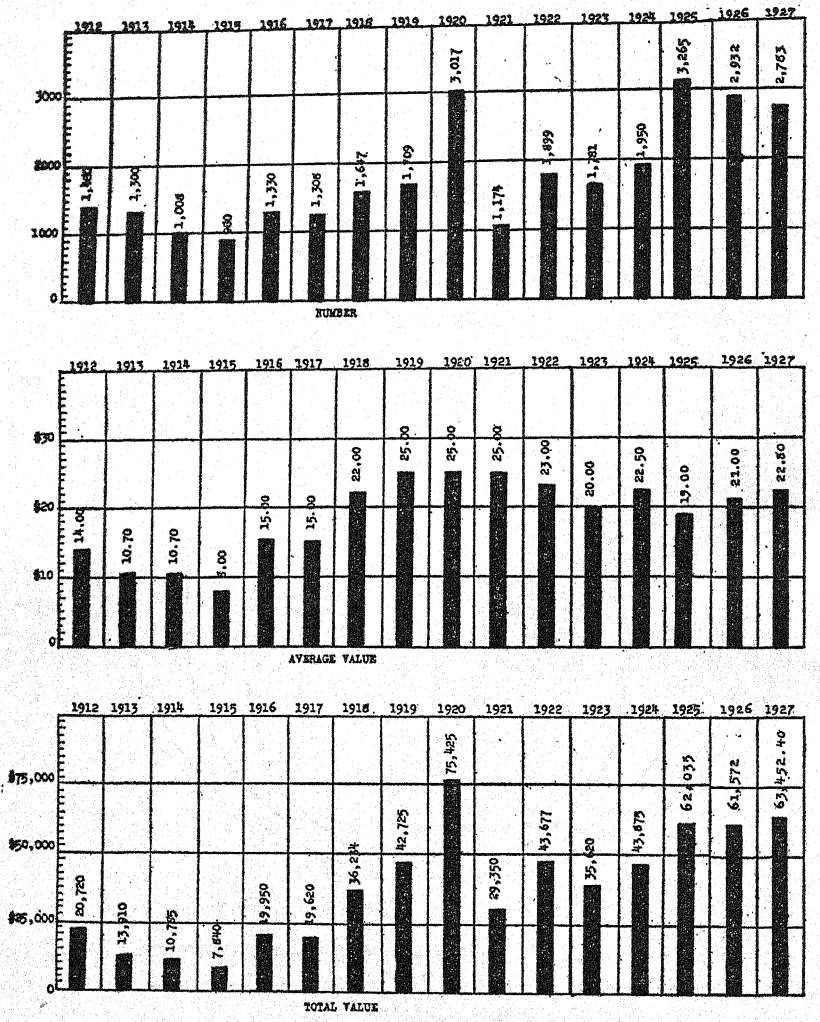



FIGURE 10.—Number, average value, and total value of land otter skins produced in Alaska from 1912 to 1927, inclusive

This should convince the most skeptical trapper that it is to his interest so to conduct his trapping operations that the young and small beavers are allowed to grow up before they are trapped, and it points out the desirability of trying to develop trapping methods and practices that will avoid the taking of the young animals, or, if they are taken, of liberating them.

An example of statistics so arranged that they can be generally visualized and advantageously used is given in Figures 10, 11, and 12.

An intimate knowledge of the conditions explains certain peculiarities in the figures, such as periodic abundance of the animals, unusual weather conditions during the trapping season, extensive

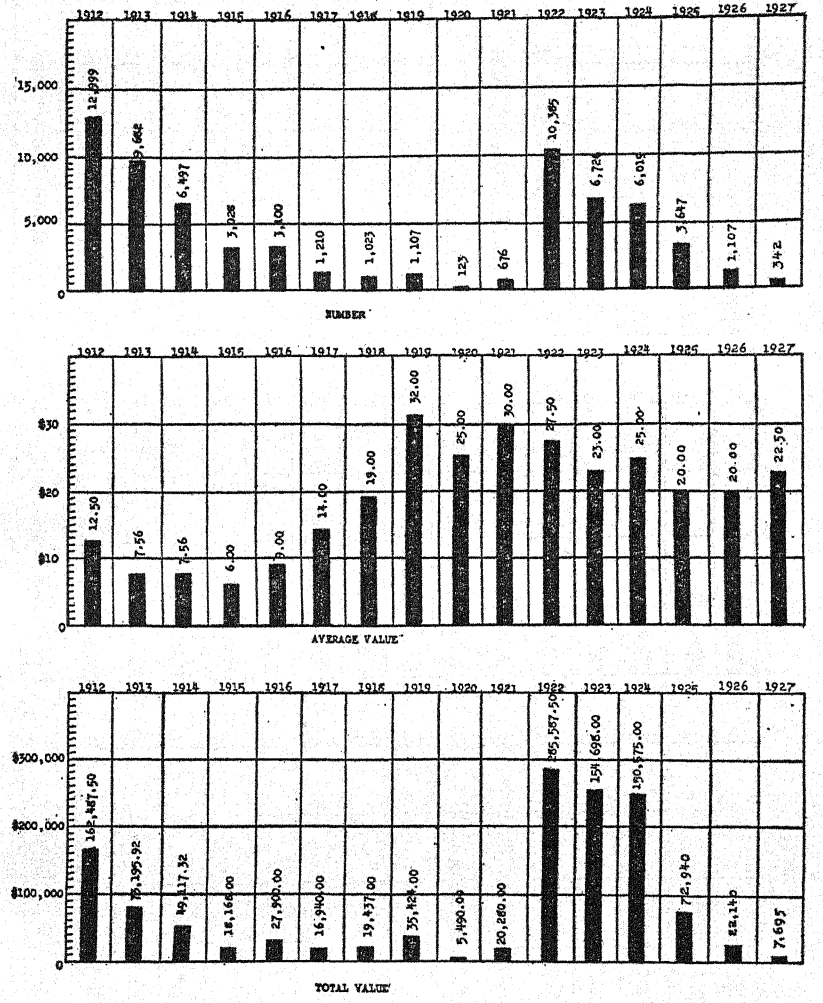



FIGURE 11.—Number, average value, and total value of marten skins produced in Alaska from 1912 to 1927, inclusive

sickness among the trappers, open and closed seasons, as well as variations due to changes in prices of the furs, and variations in numbers of animals from normal causes.

The overstocking of areas may be illustrated by the example of the farmer who overgrazes his pasture to such an extent that the

grass is destroyed and the pasture becomes capable of sustaining only a very limited number of livestock. This condition has become extensive at one time or another throughout the western United States where stock has been ranged. The situation is

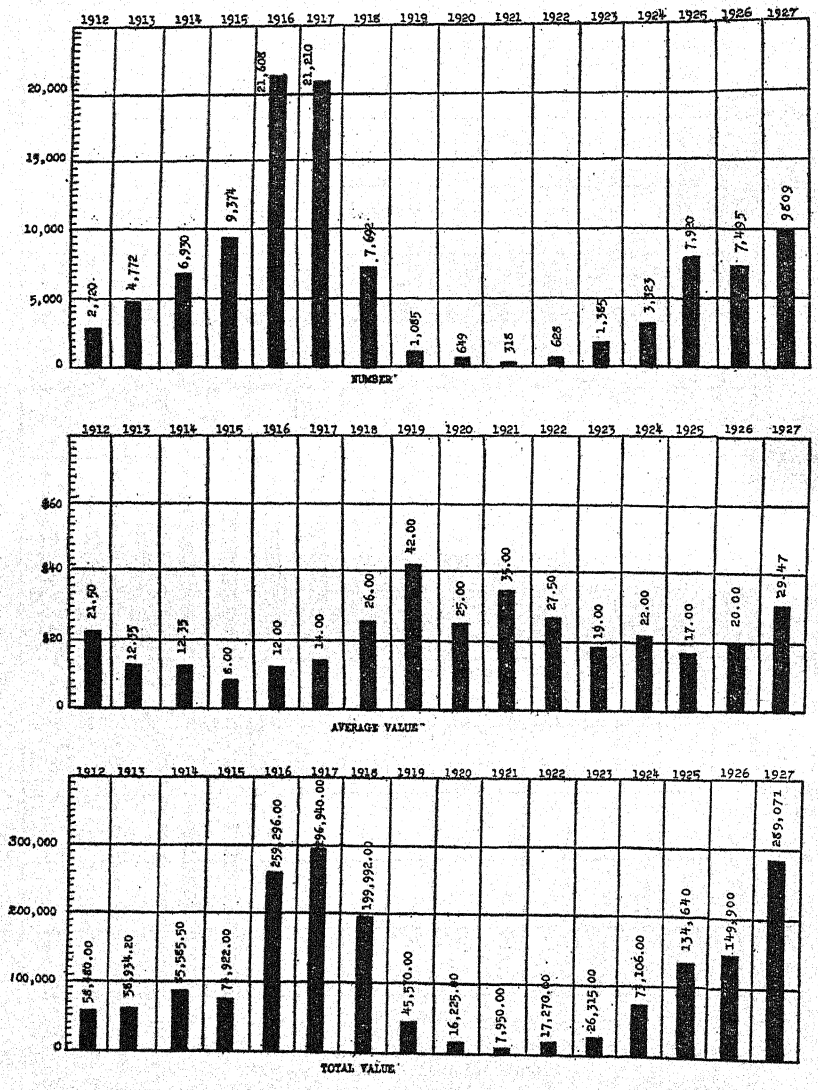



FIGURE 12.—Number, average value, and total value of lynx skins produced in Alaska from 1912 to 1927, inclusive

graphically shown by the illustration of the extermination of a species, wherein the range or vegetation is represented by the area labeled basic stock and the carrying capacity or annual forage production is represented by the area marked "Annual surplus." It can also be illustrated by the following diagram (fig. 13).

Such a method of calculating animal life as is outlined by Lincoln [3] in "Calculating Waterfowl Abundance on the Basis of Banding Returns" is well worth giving a thorough trial under varying conditions. It is a direct application of the method heretofore used of calculating the value of basic breeding stock on the assumption that the animals annually taken bear a more or less definite relationship to the basic stock.

Taylor's "Methods of Determining Rodent Pressure on the Range" [4] points out some methods of making studies of certain types of animal life and the practical application of such work.

There is real need for the development of uniformity in terminology and methods of studying and stating the data for wild-life

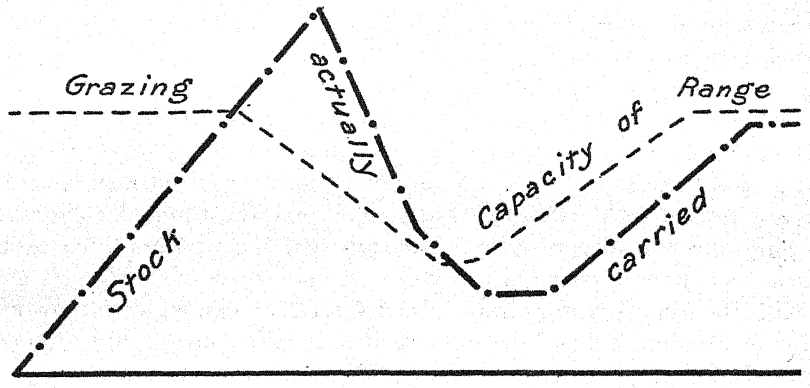



FIGURE 13.—Illustration of year by year increase from an initial stock of 10 animals having a potential annual increase of 50 per cent

administration. Fur again furnishes a good illustration. The graphs of the "Cycle of the Fur" show that there is a varying but short period when the skins of animals are in a condition of the maximum value. This condition may be compared to the condition of grain or fruit when it is said to be "ripe" or the condition of meat animals when they are said to be "finished." Among trappers the word "prime" is commonly used and is very satisfactory. However, one writer has criticized the use of the term because skins can not always be positively referred to either the groups of prime or unprime. Skins can, however, be so designated as accurately as many forms of produce can be graded, but it may be desirable to establish certain standards with a series of grades as has been done for cotton, grains, and meat.

When biologists have entered upon such studies as are needed in wild-life administration, it will be found that the problems are fully as interesting as those in other lines of biology and there is a

[3] Lincoln, F. C., Circular No. 118. U. S. Department of Agriculture.
[4] Taylor, Walter P., Ecology, Vol. XI, pp. 523–542, July, 1930.

keen satisfaction to be derived from the development of scientific data which has an immediate practical application. In addition, studying the problems of wild-life administration develops information in biology relating to life histories and to ecology that is of the utmost importance in biological sciences in general.

Even the few problems herein mentioned cause one to wonder where capable men are to be found to undertake these and the innumerable other problems that are not mentioned. It is probable that with the increase in wild vertebrate conservation which is necessary if the wild life is to be built up some of the biologists now engaged in other lines will take up the new work, but it would seem that there is a need for universities to give special training along such lines. Scholarships might well be established, and special research funds dedicated to such lines would be of great value, until such time as the public and public institutions are fully alive to the need for such work.

There is a real need for many people to devote their energies to the development of compact, forceful, and convincing ways of showing the benefits of wild-life administration and protection. As many brains with different viewpoints attack the problems of developing our wild-life resources, solutions will be produced for problems that now appear quite beyond us, and when the biologists and wild-life administrators have joined forces, we can expect a new era for proper handling of the important natural resources that hitherto have suffered so seriously from indifference and ignorance.

## SUMMARY

1. There has been extensive depletion and in some cases extinction of valuable or interesting forms of vertebrate animals.

2. There is need for increasing the wild life supply for:

*a.* Recreational uses.

*b.* Commercialization.

3. The supply can be increased by proper administration or wild animal husbandry on lands and water now producing scanty or no crops.

4. Proper administration necessitates work by competent naturalists to:

*a.* Ascertain existing conditions.

*b.* Plan steps for improving conditions.

*c.* Submit their findings and plans to those in a position to facilitate their execution.

*d.* Educate the public on the subject to the end of obtaining its full cooperation in improved wild-life production.

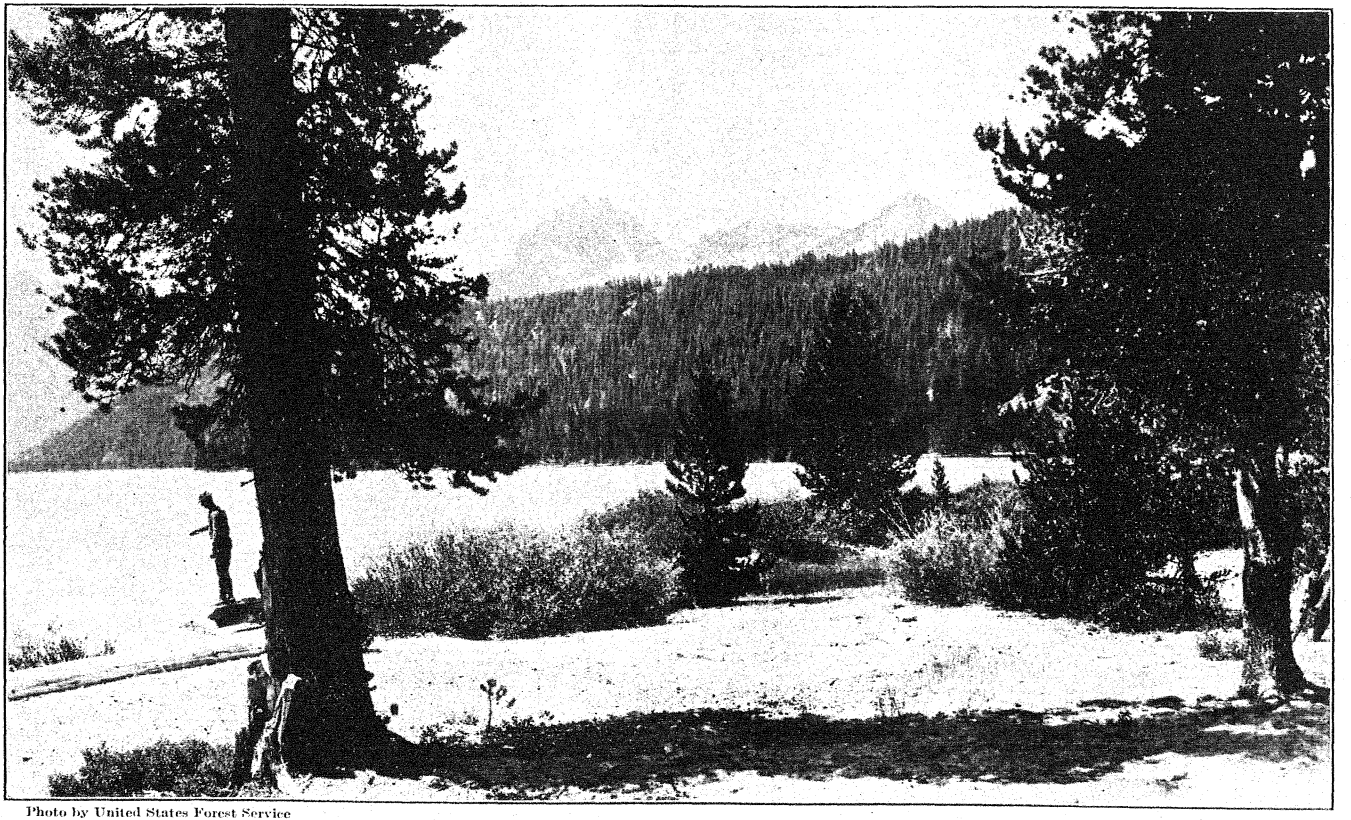
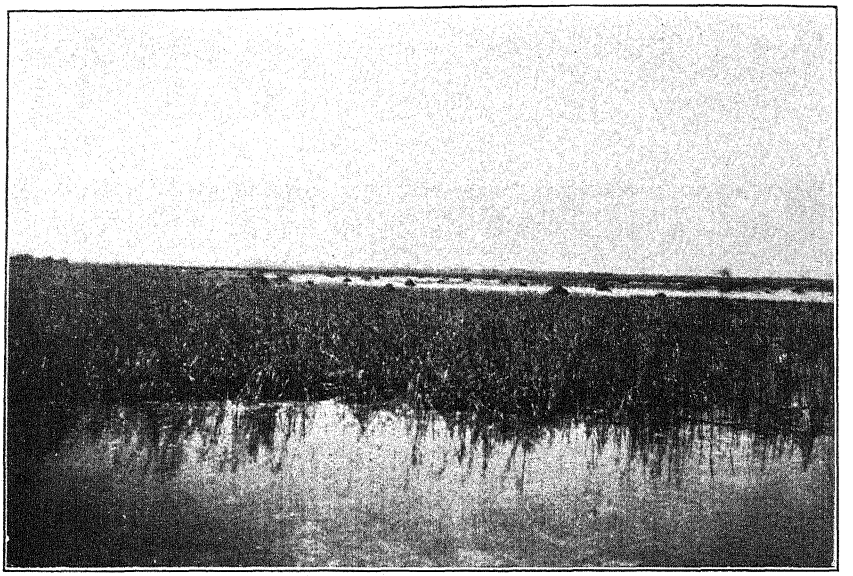
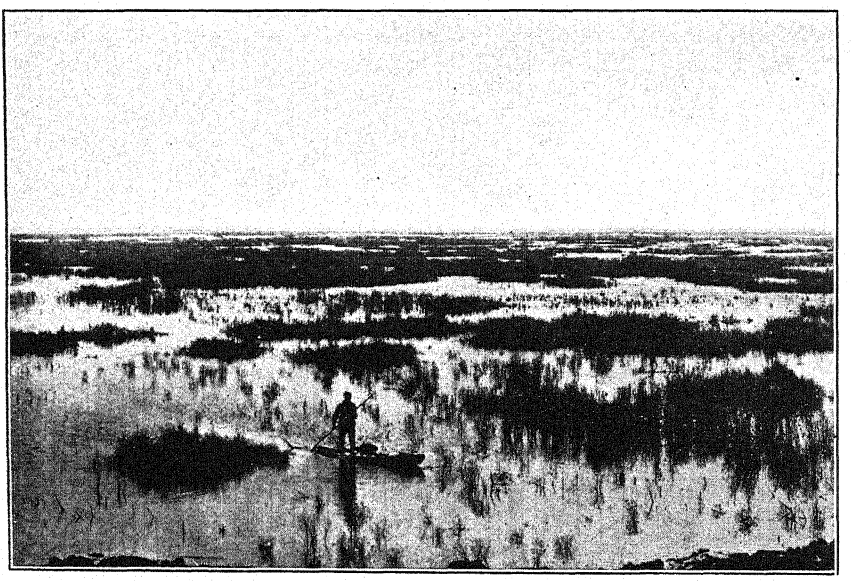


Photo by United States Forest Service

SUCH COUNTRY AS THIS WILL PRODUCE MOUNTAIN SHEEP OR MOUNTAIN GOATS, DEER, ELKS, BEARS, MARTENS OR FISHERS, LAND OTTERS, MINKS, A FEW BEAVERS, SOME WATERFOWL, GROUSE, AND FISH. IDAHO



1. A TRACT COMMONLY REFERRED TO AS WASTE LAND WHICH ANNUALLY PRODUCES MUSKRATS TO A GREATER VALUE PER ACRE THAN WOULD BE PRODUCED ON MANY FARMS RAISING USUAL CROPS AND LIVESTOCK. MARYLAND



2. A LOUISIANA MARSH FORMERLY CONSIDERED WORTHLESS, WHICH IS NOW PRODUCING CROPS OF FUR BEARERS AND WATERFOWL WORTH MORE THAN FARM CROPS ON ADJACENT DRY LANDS

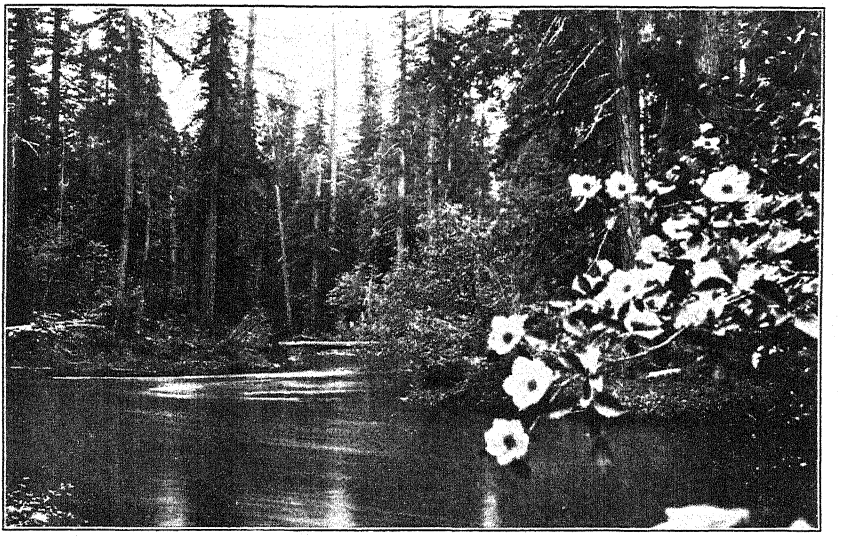


Photo by United States Forest Service

1. THE ANNUAL HARVEST HERE OF TROUT, DEER, BEARS, BEAVERS, LAND OTTERS, MINKS, AND MARTENS OR FISHERS, MIGHT EQUAL THE ANNUAL INCREASE IN VALUE OF THE TIMBER. OREGON

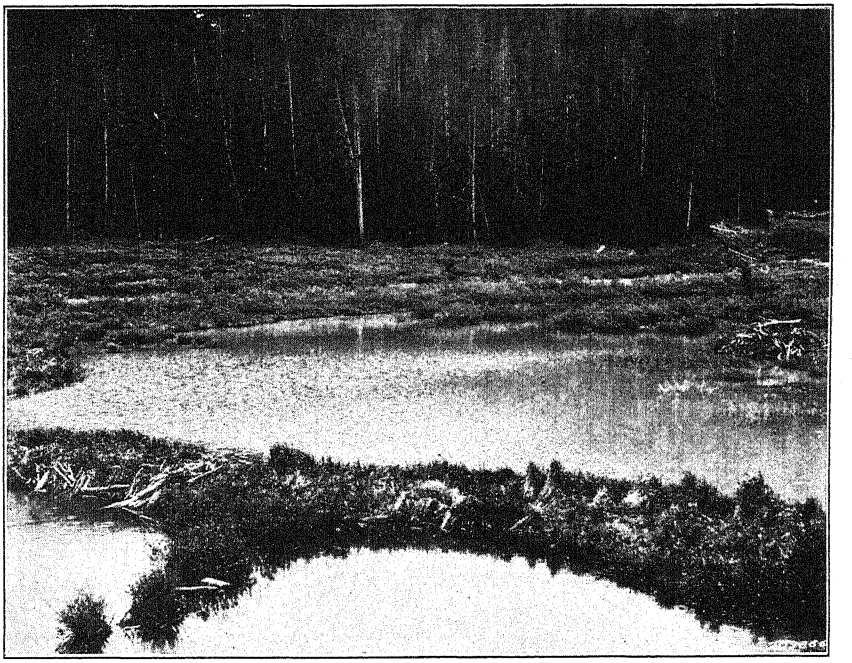


Photo by United States Forest Service

2. MOOSE, DEER, BEARS, WATERFOWL, AND BEAVERS CAN BE PAYING CROPS ON SUCH AREAS. MONTANA

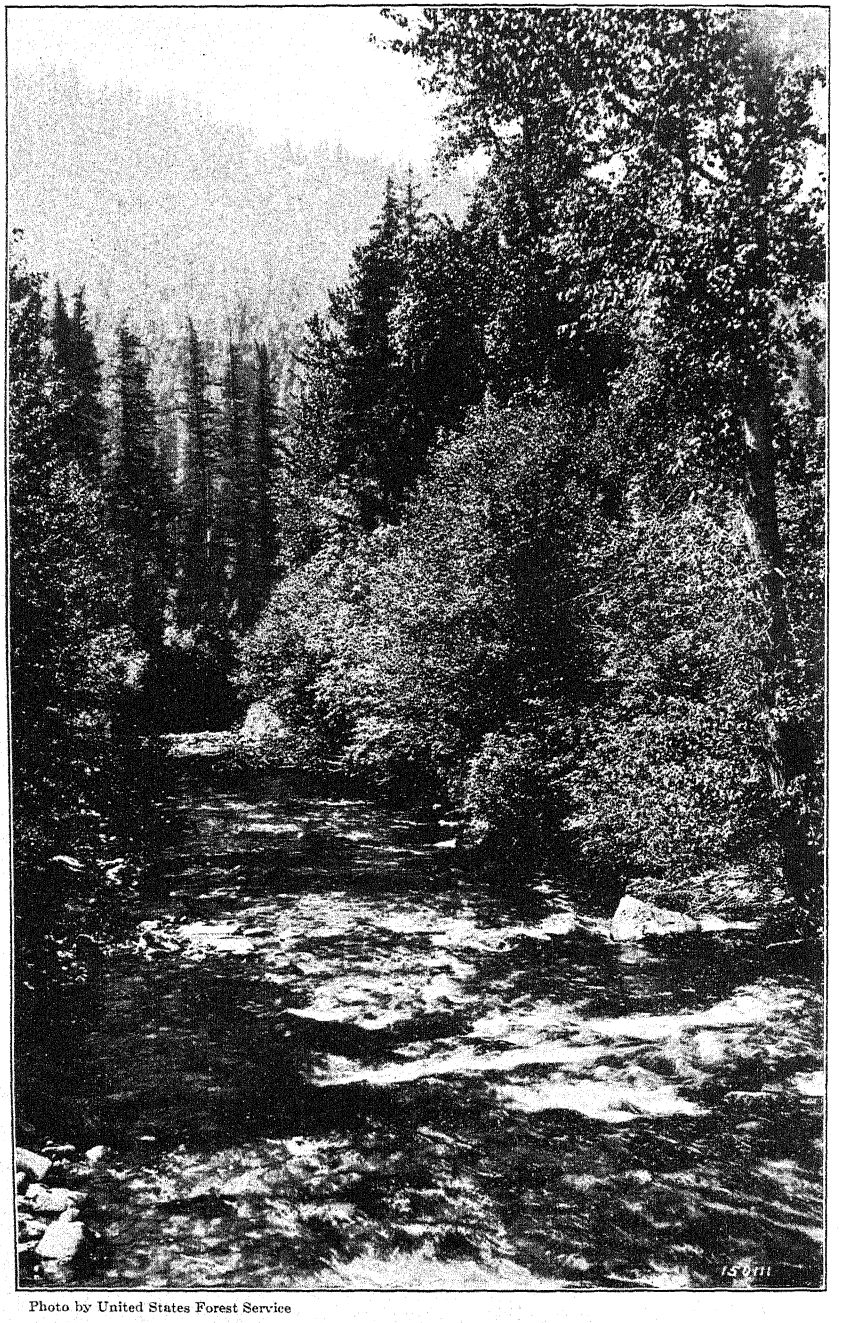


Photo by United States Forest Service

TROUT, MINKS, MARTENS, SOME BEAVERS, DEER, ELKS, BEARS, MOUNTAIN LIONS, FOXES, AND GROUSE CAN BE PRODUCED HERE IN ADDITION TO THE TIMBER. MONTANA

# THE NESTING HABITS OF WAGLER'S OROPENDOLA ON BARRO COLORADO ISLAND [1]

By FRANK M. CHAPMAN

[With 8 Plates]

## INTRODUCTION

The field studies on which this paper is based were made at the station of the Institute for Research in Tropical America, on Barro Colorado Island, Canal Zone, Panama. They cover the greater part of three nesting seasons, and the period immediately preceding them, as follows: (1) December 27, 1925, to February 20, 1926; (2) December 22, 1926, to April 2, 1927; (3) December 22, 1927, to April 1, 1928. During the first season, only part of my time was given to this work; the second and third seasons it was my chief occupation.

The colony of birds under investigation nested in a sand-box tree (*Hura crepitans*) growing about 100 feet from the northerly corner of the institute's main building; a situation favorable for continuous observation of the birds from the time of their first appearance in the morning until they retired in the evening. On the other hand, the nature of the nesting sites prohibited examination of the contents of the nests *in situ* and the only specimens of nests, eggs, or young obtained were the few that fell through the accidental breaking of the limbs to which the nests were attached. These gave a limited amount of data with which to check conclusions based on observations made from a distance.

In 1924, when the institute's station was established on Barro Colorado, a colony of oropendolas occupied a tree about 100 feet from the one now used. On June 26, 1925, possibly because it was deprived of the protection of the trees that had grown near it, this tree fell before the wind. It contained 57 nests. The following nesting season the birds selected the tree now used. The present tree, therefore, was apparently chosen because of its proximity to the one which fell, rather than for its special fitness in affording suitable nesting sites. It is a sand-box tree 132 feet in height, growing from near the bottom of a steep slope about 30 feet below the level on which the laboratory

[1] Reprinted by permission from the Bulletin of the American Museum of Natural History, Vol. LVIII.

stands. The lowest nests were about 100 feet above the base of the tree, the highest about 20 feet below its top. The nearest nests to our viewpoint at the laboratory level were distant about 80 feet. This statement is of interest chiefly from the standpoint of the photographer. With an elaborate equipment, including lenses up to 23 inches in focal length, the distance, a background of leaves, the comparatively small size and dark colors of the birds, prevented me from securing adequate photographs of them.

The conditions under which the birds were watched were far more satisfactory. My observation post was the open space beneath my house situated 15 feet higher than the laboratory, and about 100 yards from the tree in which the oropendolas nested. Seated in a camp chair with a desk board across its arms, and using a 24-power binocular mounted on a tripod, the birds, wholly unaware of my presence, seemed to be within reach of my hand. Every detail of their movements, even to the motion of the tongue when calling, could be seen clearly and with such ease that I could observe and record their actions for hours at a sitting without fatigue. I did not acquire this high-power glass until the second season. Its lack in 1925–26, when an 8-power glass was used from the laboratory level, greatly detracted from the value of that season's work.

Diagrams were made showing the relative position of the nests. Each one was numbered and its history, as far as possible, carefully recorded. When last observed, the colony of 1926 contained 39 nests; that of 1927, 29 nests. In 1928, 16 nests were built, but for various reasons, as recounted beyond, all were deserted apparently before eggs were laid, and the colony was abandoned.

It is a significant comment on our lack of knowledge of the habits of tropical American birds that, although by size, voice, and nests the oropendolas and caciques are among the best known birds of that region, their life histories are as yet unwritten. One finds short descriptions of their loud notes and the postures of the male when calling, of the appearance and, in some few cases, structure and contents of their nests. There are also several records of parasitism by *Cassidix oryzivora*, but all the statements made are based on casual or brief observations and no definite, continuous study of any member of the group has apparently been made.

The oropendolas offer, however, an exceptionally interesting subject for the field student. If the nature of the nesting site prohibits close examination of the nest *in situ*, it at least gives an admirable view of the colony as a unit and hence of the group activities of its members. The movements of the individual may also be closely followed and the colonial habits of the species enable one to observe a number of birds at the same time and under similar conditions.

Thus, one can more readily distinguish normal from exceptional habits. While I hope that my observations have covered a long enough period to reveal the more fundamental facts in the home life of *Zarhynchus*, it must be remembered that they relate to but one colony of these birds. They should be regarded, therefore, merely as the starting point for a further study of this species and of other members of the oropendola-cacique group.

## RELATIONSHIPS

*Zarhynchus wagleri* is a member of the group[2] of icterine birds known as oropendolas.[3] With the caciques[4] they are placed by Sclater in a subfamily, Cassicinae, of the family Icteridae, a distinction not currently recognized.[5]

So far as the records and my own experience[6] go, all these birds nest in colonies, build pensile nests, and nest during the dry season. The great age of these groups is indicated by the marked structural differences existing between certain of the genera which compose them, and we may assume at least a corresponding age for those nesting habits which they possess in common.

*Zarhynchus wagleri* inhabits the humid tropical zone from southern Mexico to western Ecuador. In Colombia it is known only in the Colombian-Pacific fauna. Specimens from the northern part of this range (Guatemala and probably northern Honduras northward) average slightly smaller and are somewhat darker. They represent the race known as *Zarhynchus wagleri mexicanus*. Combining characters of the most unlike members of the group, it is difficult to say to which *Zarhynchus* is most closely related. As with *Clypeicterus* and *Ocyalus* the maxilla is expanded into a broad frontal shield covering the forehead; the wings are even more pointed, the outer primaries more incised than in the latter; it differs from both these genera and agrees with the remaining members of the group in possessing occipital plumes, which are as highly developed as in *Ostinops decumanus*. In general color it is also nearest to that species and this resemblance, in connection with the fact that the ranges of the two species meet only in northwestern Colombia and in Panama, may possess some significance.

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[2] Genera: *Zarhynchus, Ocyalus Clypeicterus, Ostinops* and *Gymnostinops*.

[3] This is the Spanish name for the Old World oriole (*Oriolus oriolus*), which, like the English name "oriole," has been applied to a New World bird. It is based on the European bird's golden color and habit of building a pendulous nest, but, so far as the color of the plumage is concerned, is not strictly descriptive of any New World species to which it is applied.

[4] Genera: *Cacicus* and *Cassiculus*.

[5] Cf. Ridgway, 1902, Bull. U.S.N.M., vol. 50, pt. II, p. 172.

[6] *Cacicus cela* and *Ostinops decumanus* in Trinidad and Colombia; *Ostinops salmoni* in Colombia; *Gymnostinops montezumae* in Mexico.

In view of the fact that the subtropical and hence, presumably, more recently evolved oropendolas[7] have a yellow band or marks at the base of the maxilla, it is noteworthy that two young *Zarhynchus* taken from fallen nests on Barro Colorado, June 26, 1925, and April 1, 1927, respectively, and a young female with half-grown tail taken in eastern Panama, May 27, all have well-marked yellow, supraloral marks.

Chiefly for the purpose of affording a basis for comparison of the sexes I append a brief description of *Zarhynchus*.

*Male.*—Head, neck all around, throat and upper breast seal-brown; upper back and wings glossy black; lower back and rump and upper tail-coverts chestnut; tail bright yellow, the two central feathers and outer webs of the outer pair black; sides seal-brown shading through the flanks and ventral region to chestnut lower tail-coverts. Feathers at the base of the frontal shield elongate, those in the center of the occiput reaching an average length of 50 mm. and with a basal width of about 2 mm.; two outer primaries incised or narrowed near their ends; bill large, heavy, and sharply pointed, the maxilla expanded over the entire forehead as a broad, rounded elevated shield. Length (skin), 350; wing, 215; tail, 130; culmen, 68; greatest width of frontal shield, 21 mm.

*Female.*—Differs from the male chiefly in her smaller size. The black of the body is less extensive and less glossy but this difference is too slight to be noticeable in life. The bill is much smaller, its frontal development less pronounced, the frontal crest shorter and of fewer feathers; and the primaries are only slightly incised. In flight, the radiation of the ends of the primaries is less pronounced and this character, the absence of sound when flying, and smaller size are the characters which in life distinguish the female from the male. Length (skin), 268; wing, 153; tail, 102; culmen, 51; greatest width of frontal shield, 16 mm.

## SEASONAL MOVEMENTS

In a broad sense *Zarhynchus wagleri* is a resident, nonmigratory species. Studied locally and intensively, on Barro Colorado, at least, it is nonresident and migratory. It appears at its breeding station with remarkable regularity and at the conclusion of the nesting season leaves it. While breeding, all its wants are supplied in the forest near its home; at this time it probably rarely goes more than 400 yards from its nest tree. The extent of its wanderings at other times of the year is unknown, but its appearance within the nesting territory during the nonbreeding season is purely casual.

While *Zarhynchus* breeds during the dry season, the date when it begins to nest is not closely dependent on the cessation of rain. There has been much variation in the date on which the wet season may be said to have ended and the dry begun on Barro Colorado during the three years the oropendolas have been under observation, as the appended data from the laboratory rain-gage show.

As for temperature, it varies so little during the year that it probably plays no part in determining the season when birds nest.

[7] *Ostinops alfredi, O. atrocastaneus, O. sincipitalis.*

Possibly this is one of the reasons, perhaps the chief reason, why birds in the tropics nest throughout the year. The mean temperature for July in Panama is 81.1°; for February, 80.8°; a difference of only three-tenths of a degree. Comparison of the mean temperatures on Barro Colorado for December and January of the three years covered by my studies of *Zarhynchus* shows a slight decrease in the second month the first year, a negligible increase in the remaining two. The data follow:

*Mean Temperature for December and January 1925–1928*

| Month | Temperature | Month | Temperature |
|---|---|---|---|
| | ° | | ° |
| December—1925 | 82.0 | January—1926 | 80.5 |
| 1926 | 79.5 | 1927 | 80.2 |
| 1927 | 80.1 | 1928 | 80.6 |

*Table of rainfall, in inches, on Barro Colorado Island during December and early January, 1925–1928*

DECEMBER

| Day of month | 1925 | 1926 | 1927 | Day of month | 1925 | 1926 | 1927 |
|---|---|---|---|---|---|---|---|
| 1 | 0.05 | 0.81 | 0.64 | 18 | 0 | T. | 0 |
| 2 | .22 | .13 | .10 | 19 | 0 | T. | 0 |
| 3 | 1.67 | .22 | 0 | 20 | .02 | 0 | .10 |
| 4 | 1.76 | .25 | .15 | 21 | 0 | T. | 1.40 |
| 5 | .47 | .24 | .78 | 22 | 0 | .45 | 1.50 |
| 6 | .13 | 3.06 | 0 | 23 | 0 | .62 | .40 |
| 7 | 0 | 1.36 | 0 | 24 | 0 | .18 | .03 |
| 8 | 0 | T. | .30 | 25 | 0 | 0 | 0 |
| 9 | 0 | .04 | .36 | 26 | 0 | 0 | .08 |
| 10 | 0 | 1.02 | .07 | 27 | 0 | 0 | .83 |
| 11 | 0 | .34 | .02 | 28 | 0 | .32 | 0 |
| 12 | 0 | .89 | 0 | 29 | 0 | .04 | 0 |
| 13 | 0 | 1.05 | 0 | 30 | 0 | 0 | 0 |
| 14 | 0 | .55 | 0 | 31 | 0 | .08 | 0 |
| 15 | 0 | .13 | 0 | | | | |
| 16 | 0 | .11 | 0 | Total | 4.32 | 12.22 | 6.76 |
| 17 | 0 | .33 | 0 | | | | |

JANUARY

| Day of month | 1926 | 1927 | 1928 | Day of month | 1926 | 1927 | 1928 |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 0.41 | 0 | 10 | 0.40 | 0.96 | 0.17 |
| 2 | 0 | .02 | [1] 0 | 11 | 0 | .08 | 0 |
| 3 | 0 | 0 | 0 | 12 | 0 | .48 | .10 |
| 4 | 0 | 0 | 0 | 13 | 0 | 0 | 0 |
| 5 | 0 | .19 | 0 | 14 | .20 | 0 | 0 |
| 6 | 0 | .12 | 0 | 15 | 0 | .18 | 0 |
| 7 | 0 | 0 | 0 | | | | |
| 8 | [1] 0 | 1.25 | 0 | Total | .76 | 2.81 | .34 |
| 9 | .16 | .12 | .07 | | | | |

[1] *Zarhynchus* began to build nests.

The end of the wet season, therefore, varied from December 6 in 1925 to at least January 12, in 1927. That this variation was not reflected in the dates when the oropendolas began to nest will be seen from the following data:

Dates at which *Zarhynchus wagleri* began to nest at Barro Colorado Laboratory, 1926–1928:[8]

1926 Nesting began January 8
1927 Nesting began January 8
1928 Nesting began January 2

This remarkable periodicity indicates the regularity of the annual physiological cycle of the species. While in the main coincident with the dry season the birds' exact nesting period does not appear to be affected by the annual fluctuations in the date when the wet season ends, but rather is governed by those sexual changes which mark the approach of the season of reproduction. They prompt the birds to go, we may say to migrate, to the nesting tree. The extent of the migration we do not know. The birds may spend their lives within a radius of not more than a mile or two from the place of their birth. The significant fact is that the journey to their nesting range is begun in response to a periodically recurring physiological condition, that it is made regularly to a definite place, presumably before visited, and that as such it is fundamentally as true an example of migration as though it were made from the South Temperate to the North Temperate Zone.

The case is paralleled by the return of tropical sea birds to their nesting grounds situated within the limits of their winter wanderings, to which I long ago called attention in a paper[9] designed to show that primarily bird migration was, and is, induced by those developments in the sexual organs which precede the season of reproduction. Hence it follows that if because of sterility or immaturity this development does not occur, the bird in which it is lacking may remain in its winter quarters throughout the nesting season.[10]

The members of the laboratory colony do not all begin nesting at the same time. Just as with migrants to the Temperate Zone, there are late arrivals. Thus in 1926 new nests were begun as late as February 11, in 1927 on February 13, and 1928 on February 7.

Short visits are paid to the nest tree some days before nest building actually begins. In the season of 1926 I made no record of such visits. The following year I reached the island on December 22, 1926, and the appended observations were recorded before January 8, 1927, when nest building began.

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[8] Compare also the nesting dates given beyond for the black-throated hummingbird (*Anthracothorax nigricollis*).

[9] 1894, "Remarks on the Origin of Bird Migration," The Auk, vol. XI, p. 12.

[10] In mid-July, 1922, I took specimens of both sexes of the following Arctic-breeding shore-birds in southern Ecuador: *Squatarola squatarola, Numenius hudsonicus, Limnodromus griseus scolopaceus.* None had the sexual organs enlarged. See "Distribution of Bird-Life in Ecuador," 1926, Bull. Amer. Mus. Nat. Hist., vol. LV, pp. 192, 194.

SEASON OF 1926–27

December 23. Two males call in the tree in the early morning and then soon depart.

December 24. No birds seen in the tree; one heard in the distance.

December 29. Three reported but sex not stated.

December 30. A male calls at 7.15 a. m. and later one female visits the tree.

December 31. A male calls in the early morning and several females come for a short time later.

January 1, 1927. One male and one female came.

January 2. One bird heard in the distance.

January 3–5. Observer absent.

January 6. *Zarhynchus* shows a group interest in the nest tree. First came a male with 4 females, then 2 males with 8 females. The first group left with the male, in the second, the 2 males went off together while, later, the 8 females flew off in another direction. Nothing is decided and no actual construction has begun. The birds are site hunting and follow each other closely. When 1 female goes to inspect a new limb all the others follow her. There was one combat between 2 of them; at 9 a. m. all the birds had left the tree for the day.

January 7. At 8 a. m. 2 males and 3 females came to the nest tree for a short stay, the females following each other about. At 8.30, 2 males flew over alone; they lit in the forest and called. Three males in the tree call; no females come. A little later there were 8 females and 1 male in the tree. The females examined remains of old nests and soon left together.

January 8. Nest building began.

SEASON OF 1927–28

In the nesting season of 1927–28, I reached the island on December 22, 1927, and my notes, until the birds began to build, are as follows:

December 22–25, 1927. No oropendolas seen.

December 26. At 8.30 a. m. a male calls a few times and leaves.

December 27. No birds seen in nest tree; one heard in the distance.

December 28. Male visits tree and calls at 6.20 and 8.20 a. m. Heard later in the distance but not seen in the tree again.

December 29. At 7.30 a. m. 2 males call in the tree. Later 3 females, acting as a unit, fly from place to place prospecting. Grapple and whirl while fighting, once. A male in the tree but, as usual, they ignore him.

December 30. Two females prospect together. A male calls, definitely addressing them and thus beginning his prolonged courtship.

December 31. Observer absent.

January 1, 1928. Two females worked on an old foundation, and a male called vigorously.

January 2. Nest building began.

It will thus be seen that preliminary visits are paid the nest tree some days before nesting actually begins.

## THE QUESTION OF A SECOND BROOD

The nesting season of *Zarhynchus* is so closely associated with the dry season that it is difficult to believe that they nest also in the wet season. Nevertheless, the facts indicate that at least some birds

breed after the rains begin, though whether their activities represent an actual second breeding season or are individual I am unable to say. I, myself, have not been on Barro Colorado between April 2 and December 22 and for the following observations, made during this period, I am indebted chiefly to Dr. J. Van Tyne of the University of Michigan.

Dr. Van Tyne writes that only one of the 57 nests in the tree that fell on June 26, 1925, contained anything. This nest held two nestlings nearly ready to fly. A male collected on this date had testes measuring 17 millimeters in length.

On July 8, 1925, 43 nests were counted in the oropendola colony situated about 400 yards from the laboratory; 8 or 10 birds were present and at least 3 or 4 nests were in use. A male collected at this colony on July 9 had testes measuring 19 millimeters in length.

In 1927, after my departure on April 2, Dr. Van Tyne reports that on April 5 he saw young fed for the last time in nests that had been begun on January 8 and adds the following observations:

April 5. Noticed two females fighting over what seems to be a prospective nest site somewhat to the right of any of the present nests.

April 9. Returning this afternoon from Panama City (Pearl Island trip) I find a whole group (I count a dozen) of new nests being started. The group is situated immediately to the right of and somewhat lower than the old right-hand group of nests. One nest is well along (one-third length) and the rest merely started. I have seen no bird yet using any of the five marked (old) nests. I suppose they are empty by now. Are not the new nests being built for second broods?

April 11. The nest building is progressing rapidly. There are now 19 nests under construction and more apparently being started. The males have been much more noisy since this new nest building began. Also the false-alarm business (i. e., cackle and dive for safety) has been much more frequent. *Legatus* and *Cacicus* are much in evidence. *Legatus* looks into some of the old nests but does not enter. *Cacicus* merely sits around and sings.

April 12. I can now count 22 new nests. Only about four of the old nests seem to be still occupied. The females that are building are continually stealing nesting material from each other and from old nests.

April 14. There are 10 of the nests which are now completed as far as the outside is concerned—they continue to work inside. All of these nests are strikingly shorter than the first brood nest. Most of them are barely a foot long.

April 19. At 6 a. m. (8 minutes before sunrise) the oropendolas were nearly all at their nests about to begin work. 6.30 p. m. none of the females are roosting in the nests yet. But there are several of the old nests still in use.

April 21. Only 18 of the new group of nests appear to be under active construction. Others seem to have stopped entirely and are probably discarded. To-day 6 new nests were started in a separate group about half-way between the two old groups of nests and some 10 feet lower. All are close together on the same branch. Why do they do things by groups like this? What is this smaller group within a nesting colony?

On April 26 the wet season began—3.78 inches rain. Rain continued—averaging nearly an inch a day. This seems to have stopped the oropendolas. They

continued to hang around for nearly a week but finally gave up and left entirely. *Legatus* is still hanging around (May 11) as ineffectual as ever. *Cacicus* makes rare visits to the abandoned colony but the oropendolas (*Zarhynchus*) almost never.

In July, 1928, Mr. Zetek reported to me the presence of 11 oropendola nests in a large outstanding tree near the observatory on the summit of the island. These nests had not been built when I left the island on April 2, nor were the birds known to nest in these trees at any previous time. Mr. Jay A. Weber, who was on Barro Colorado from July 22 to August 10, 1928, at my request, made repeated observations of these nests and he reports that no oropendolas were seen near them or indeed on the island during his stay.

Possibly these nests were built in April before the rainy season began, by the birds that had been prevented from nesting in the sand-box tree at the laboratory. On the other hand, taken in connection with Dr. Van Tyne's observations, recorded above, this late building may indicate a regular attempt at the production of a second brood.

## VOICE

The notes of *Zarhynchus* are loud, varied and frequently uttered. Those uttered by both sexes are (1) the characteristic blackbird "chuck" or "chut," which is apparently a location call or conversational note, and its varying tone doubtless conveys varying meanings; (2) a "cack-cack" development of the call note which expresses suspicion and alarm. This is given by the male more frequently than by the female whose voice joins that of the male in the presence of actual or suspected danger, as described beyond. The call is then louder, uttered more rapidly and resembles the sound produced by a small watchman's rattle, or "matraca"; (3) a whining call which seems to be a note of combat, real or threatened. This is given by the males when two or more at close quarters are courting the same female, and by the females when in the contest for a nest site they grapple and whirl downwards. The females also sometimes whine just after entering the nest, but the significance of the note is then not apparent.

The notes peculiar to each sex are the female's gasping "wee-chuck-chuck-chuck," a low husky gurgle which one bird addresses to another in disputes over the nesting site, and the male's announcement of presence and his song. I distinguish between these two calls of the male, but lack of experience with the species in the non-breeding season makes the distinction an arbitrary one.

I at once confess my inability to transcribe the male's calls either by notation or syllabification, and faith in my power to convey even an approximate idea of them is weakened by the fact that, for the

greater part, descriptions written one year mean little or nothing the next! What I have termed the announcement of presence call is uttered before courtship begins, when, for example, the male is alone in the nest tree. I write it as "agua" or "waco" or "chap-pa-qua"; "hope you choke."[11] The tone is loud, deep, liquid, and gurgling and the call is usually interspersed with "chucks." The courtship, or "crash" call, which I consider the male's real song, begins with the one just described and adds a sputtering crackle ending in an explosive crash. In my notes I have also termed this remarkable production a sputtering, masticatory ejaculation. The polysyllables help convey some idea of its character. This call, as described under courtship, is given with obvious muscular effort. It can, indeed, be seen coming as the bird's body begins to swell from below upward and, rising on tiptoe, he delivers his vocal appeal, then sinks back deflated. Of all these themes there are endless variations and combinations and as the season advances changes occur which, while evident to the ear, are too subtle to be put on paper.

### WING "NOTES"

The flight of the female is essentially noiseless, but the flight of the male is often accompanied by a sound, evidently produced by the passage of the widely radiating, emarginate outer primaries through the air. This sound varies in rhythm in response to the character of the bird's flight. It is apparently under the bird's control and may be withheld, when the flight of the male is as noiseless as that of the female. It probably has some sexual significance. As a rule it marks the time of the bird's wingbeat as with a loud "fluff, fluff, fluff," he flies steadily with even strokes or passes on deep, swinging loops. When the male pursues the female in courtship-flight it is a loud startling, rushing roar, such as might be produced by the sudden violent tearing of some textile. On several occasions it accompanied a peculiar flight as the bird pointed its bill toward the ground and, with short, jerky wingbeats, produced a staccato "plop, plop, plop." This may have been some form of sexual display.

### THE QUESTION OF TERRITORY

The question of territorial rights while nesting apparently does not enter into the location of an oropendola colony. On Barro Colorado three nesting colonies of these birds are known. One is 400 yards from the laobratory colony, the other nearly two miles from it in the

[11] The latter phrase is the only one that has held in my notes for two years and for this reason I give it.

opposite direction. Birds apparently en route to the nearer colony sometimes stop in the laboratory tree and mingle with the local birds without their presence being questioned.

Nor do groups within the colony appear to be concerned by the question of boundaries. The first bird to arrive selects its group location from the unoccupied field, the choice being made by the females. Each year of my observations the first group to arrive has selected a different location. Always, however, a situation was chosen that had been used before. Here the point of attachment, which is usually all that is left of the preceding year's nest, offered an attractive place for the beginning of a new nest.

The nests are always built on the southerly and westerly, which is the leeward, side of the tree during the period of trade winds that prevail in the dry season. Here the nests receive some protection from the windward side of the tree, and it is probable that the birds can enter them more readily flying upwind than they could when flying down wind.

The tree is large enough to afford sufficient space for subsequent groups without arousing the enmity of those already located, and I have seen no ill-feeling displayed between the members of different groups as such. Size is, indeed, to be desired in a colony, and the larger its population the more protection do its component individuals receive from their common enemies.

It was soon evident that the birds were not monogamous, but it was by no means clear whether they were polygamous or promiscuous. The relationships of the males to one another were also to be determined. No reference to these subjects has been found in the literature concerning oropendolas and caciques.

## COURTSHIP AND SEXUAL RELATIONS

To determine the sexual or marital relations of the members of an oropendola colony is one of the most interesting and at the same time most difficult problems connected with the study of these birds. At the time of my departure the colony of 1926 contained about 6 or 7 males and 39 females; that of 1927, 5 or 6 males and 29 females; that of 1928 was never fully organized. In each case the number of females given was determined by the number of nests. Unattached females may have visited the nest tree, but they did not function as members of the colony.

The opening of the nesting season is announced by the location call of the male, given from the nest tree, on numbers of occasions, some days before nesting actually begins. Females may or may not be present at such times; however, should there be any in the tree the male pays no attention to them. It is not until they begin to build

that his prolonged courtship actively begins. He then takes a post usually above the working females and addresses the group collectively; or he focuses his attention on a single bird (but not always the same bird). Generally he perches on the nest branch above her and repeatedly utters the courtship or "crash" call. As the season advances and the period of egg deposition approaches he presses his suit with greater energy, and at its maximum his demonstration is thus described in my records of February 18, 1927:

> The usual position of the male when addressing the female is above her, often on the limb to which her nest is attached or, should she be inside, at its entrance. From this point of vantage he leans down toward her, his blue eyes glare as though they would pop from their orbits, his crest feathers are elevated and expanded laterally, his wing tips are crossed above his tail, and the fluffy feathers of the lower back are spread out over the edges of the inner wing quills. This attitude is invariably accompanied by the "crash" or courtship call—indeed, is assumed for the purpose of uttering this call. In the delivery of it the bird rises on his toes, as it were, nervously flits, while slightly spreading the tail, raises the dorsal feathers, and fluffs out the body feathers chiefly of the flanks. The movement of the body feathers may be caused by the muscular exertion incident to the delivery of his notes, but the spreading of the back feathers seems a part of the display. When not specifically directed toward a female but addressed generally to a group, the bird's attitude is more erect, like the normal perching position, the tail is not flitted and the performance is less tense, less excited.

This muscular and vocal demonstration evokes no response from the female who, acting as though wholly unaware of the male's presence, continues without interruption her nest building and her journeys to and from the forest. The male may accompany her on these journeys or he may turn his attention to another female.

It is not apparent that a male has any group relations or group rights. As many as six males have been seen courting in one group at the same time and they fly from group to group. At an unexpectedly early date the male pursues the female in what appears to be a mating flight, though I have never seen it lead to mating. In 1927 this act was first observed on January 12, four days after nest building began. In 1928 it occurred within the first week of building. On these occasions the male with a rush and a roar of wings pursues the female at full speed while she twists and turns and apparently spares no effort to evade him. Usually the birds are lost to sight in the forest but in every case where the flight has been watched to its conclusion the female alights in a tree, the male perches near her and the incident is closed. Frequently the pursuing male is joined by a second and even by a third when the affair becomes a thrilling exhibition of flight power not without its dramatic appeal. As the nesting season advanced it was observed that each male concentrated his attention on a certain female which he accompanied to and from

the nest and that his rights appeared to be recognized by other males none of which disputed his claims. The male at this time did not rush after the female but went with her quietly, as though he were her accepted mate. My entry of February 26, 1927, in regard to the owner of nest No. 5, group 1, who is later referred to in connection with the loss of her nest, illustrates this habit; it reads:

> Male accompanies female with great regularity to and from the nest waiting immediately above while she is inside and leaving just after she does. She always leads both going and coming. Their flight is normal, there is no rush of pursuit, and no other male interferes.

While waiting for the female to come out of the nest the male may now be silent or he may call a rather automatic call without any of the action and vocal energy of the courtship period. On February 28 and March 1 a male with a black-tipped bill was recorded regularly accompanying the female of nest No. 17, group 2, in the manner above described. This nest was begun February 7 and it is probable that the female was about to lay.

Further evidence indicative of an understanding between the sexes is supplied by observations in which the female not only acknowledged the presence of the male, but apparently caressed him. Thus on January 27, 1926, and February 10, 11, and 22, 1927, a female perched by the side of a male, away from the nest but in the nest tree, was seen to pick at or stroke the male's plumage. The record of February 11 reads: "A female picks at the head of a male gently (a caress?) several times. He apparently is conscious of the attention and welcomes it." Quoting again from the entry for February 11: "A female perched near the place where one was observed yesterday runs her bill through the male's neck feathers, while he, with bowed head and half-open bill, seems to enjoy the proceeding." Again, on February 22: "A female, in the body of the tree, caresses a male. Two other males come, but the female pays no attention to them and continues picking at the feathers of the first male. She then flies off with him leaving the other males."

Since this attention on the part of the female was not restricted to the immediate vicinity of the nest, where it could be readily observed, it may have been indulged in far more frequently than my records show. Together with the regular association of a male and a female for a short time it leads to the conclusion that at least during the period when the ova require fertilization a male and a female associate as a pair.

After incubation begins the male shows no further interest in the female. In this connection my entry for February 22, 1927, reads: "No. 5, group 1, is the only bird of the seven in the group that attracts a male, from which I conclude that the other six have laid."

And on February 23, I find this: "No males in group 1 to-day. Their attention is devoted to the builders in group 2." February 28 I quote further: "No males have been seen in group 1 since I can remember."

Although the males are such ardent and persistent wooers, they exhibit no really pronounced sexual jealousy. Possibly its absence is due to the excess in the numbers of females over males. But in the small colony of 1928, when there were probably half as many males as females and the competition for a mate should have been keener than in the preceding years, no change was observed in the relations of the males to one another. When several males (I have seen four) court the same female simultaneously the situation is apparently threatening. The birds whine excitedly and an attack seems imminent but at the worst it results in a pursuit in which one bird retreats slowly before another, flying from limb to limb but not usually leaving the nest tree. No notes are uttered—the whine seems to be the only battle cry—there is no resistance and hence no fighting, and the whole affair is quiet and dignified. On one occasion (January 26, 1927) one male drove a second from perch to perch and finally out of the nest tree, then out of three other trees, and finally into the forest where they were lost to view, but it was done quietly and slowly. It is only the females that fight.

## THE SITE

In the tree now occupied by the laboratory colony, the nest site is a single terminal, "dripping" or downward pointing branch or twig about the thickness of a lead pencil. Nests preserved from the tree that fell show that its terminal branches had an upward curve, creating, therefore, a short horizontal section at the turn which offered a more favorable place of attachment for the nest than is given by the branches of the tree now occupied. In any event, the site should permit the nest to swing free without danger of entanglements with near-by limbs even when, as sometimes happens, it is blown to an almost horizontal position.

If the birds of a group arrive and work together they usually build nests as near to one another as the available sites permit. The selection of a site may be made at once and peacefully, it may cause the display of some animosity accompanied by actual fighting, or it may be the occasion of a remarkable performance extending over several days. In the first instance, nest building proceeds at once without friction and it is possible that these birds have been associated before. In the second instance the birds grapple claw to claw and, fighting with their bills, whirl downward like a single bird with set wings extended. When within 10 to 20 feet of the

earth they separate, fly to the nearest perch and sit there quietly for a few seconds side by side. Then they usually return to the nest site. These conflicts may be repeated from time to time but cease when nest building is under way and right to the possession of a site is acknowledged.

An extreme illustration of the desire for close companionship while nesting occurred in the season of 1928. On January 31 two females began to build nests Nos. 3 and 4 of group 2. The birds were on friendly terms, selected sites not more than a foot apart, and proceeded quietly with their work. On February 3, when the nests were well started, they were joined by two more females who insisted on aiding them in the construction of their nests. I quote from my journal:

> Nest No. 3 is the more advanced and the newcomer confines her efforts to the upper or attachment portion where she is permitted to work by the owner. No. 4 has room for only one worker and every attempt on the part of the volunteer to assist is at once resented by the owner. The birds then lock grips and whirl downward fighting and squealing as they fall. An occasional floating feather shows that these aerial combats are not mere matters of form. For the greater part of the time the two birds sit motionless, with bills half open glaring fixedly into space; No. 4 on her nest, the would-be helper on a branch distant only a few inches. For at least 10 minutes they hold this pose then spring at each other and, grappling, whirl downward.

The first-named volunteer finally built a complete nest, using the attachment of No. 3 for her foundation, while the one who for some time persisted in her efforts to assist the builder of No. 4, finally built a nest of her own from an immediately adjoining branch.

In some cases, however, the matter of site ownership is not so quickly settled, when the actions of the builder of nest No. 4 and her rejected assistant developed the singular performance to which I have before referred. The most pronounced and prolonged dispute of this nature was made by two females in group 2, of the 1927 nesting season. These birds were first observed at 7.35 on the morning of January 19, facing one another on terminal site twigs about 1 foot apart. One went through the motions of the male's "crash" call repeatedly. I could see its bill moved but could hear no sound. The other, with head bowed, listened. Finally they grappled and fell fighting. The struggle thus begun lasted for five days before each bird was reconciled to the presence of the other, and at the end of this time each began building on its own site. Sometimes one, sometimes the other, "held the floor," but they never both called together and the bird addressed, apparently oblivious of all else, gave her entire attention to the speaker. Seen at such times, one would assume that the calling bird was a courting male, the silent one a receptive female, but this illusion would be destroyed when the listening bird would claim the privileges of the floor and speak as vigorously as her protagonist,

the argument often ending in a grapple and fight as they whirled downward. I quote from my journal records of illustrative observations:

January 20, 7.55 a. m. Two females face each other, bills about 3 inches apart and call alternately; crests erect.

January 21, 9.44 a. m. Nos. 1 and 2, group 2, at same sites as yesterday. No. 2 assumes a downcast (listening) pose, No. 1 addresses her. Both now facing each other only 8 inches apart; a laughable performance, crests arising as they speak. (This was continued until 10 a. m. when both picked at old nesting material.)

January 22. No. 1, perched above No. 2, who is on her site, calls frequently, addressing No. 2 below, who, with her head bowed in the usual pose, eyes half-closed, bill sometimes partly open, apparently listens intently to the notes No. 1 is practically pouring into her ear. A male alights on the limb above, and shakes it so that Nos. 1 and 2 lose their balance. No. 1 falls on No. 2, they grapple and whirl downward, but return at once and assume their former poses and actions.

January 24, 7.20 a. m. Nos. 1 and 2 still at it; the form of approach this morning being the statement and counter statement. They never call together but one follows the other and I can hear the husky gurgle of both.

On this date the discussion closed, and although there had been some attempt at nest building, it was not until January 25 that work was definitely begun. It then appeared, as will be shown later, that both these birds were inexperienced builders. Possibly they were building their first nest and hence had been selecting their first site. Several other couples in group 2, 1927, acted as did Nos. 1 and 2, but in no other instance was the dispute so prolonged. This group was not definitely organized and seemed to be composed largely of individuals who had not before been associated.

## NEST BUILDING

When the nest building instincts are fully developed the birds work regularly and persistently giving the greater part of each day to their task. During the building season there is a variation of only about five minutes in the time of the sunrise (6.35–6.40) and correspondingly little variation in the birds' working hours. In January, with clock-like regularity, one or more males call from the nest tree at from 6.30 to 6.35 a. m. and 20 to 30 minutes later the females arrive and begin their day's labors. For the succeeding four hours they are steadily employed in gathering material and using it. They receive no aid whatever from the male either in securing material or building. He, however, is almost constantly with them, both while they collect building material and while in the nest tree, and his unremitting attentions and frequently uttered calls may prove a source of encouragement.

Toward midday the birds usually retire to the forest and the nest tree is deserted. In the early afternoon work is resumed and con-

tinued until about half-past five o'clock when the birds in a body go to the forest, generally taking the same direction, perhaps to a regularly frequented roost. From this schedule there is, of course, more or less variation, and as the season advances the birds retire later.

Comparatively few nests survive the rainy season and those that do remain are frayed and ragged. A new nest, therefore, is built each year. On one occasion, after a rain, a bird was seen to use some wet, and hence weavable, material from an old nest in the construction of its home, but, as a rule, only the attachment of the preceding year's nest enters into the building of the new one.

Strong but pliable material is required by the weaver. A green tendril 8 to 10 inches long is much used, particularly in the early stages of the work. This, like twine, can be wrapped about a limb many times, forming, in effect, the foundation of the nest bag. Air rootlets, fine strips of bark, filamentous blossoms, plant fibers, string-like strips from the stem of *Monstera* torn off by the strong, serviceable bill of the bird, what resemble weed stalks (but no twigs) form the greater part of the nest bags examined. I use the term "nest bag," for the pensile structures seen hanging from the nest tree are merely the receptacles for the nest proper. This is composed of nearly a hatful of fragments of soft leaves and bark and short pieces of fiber loosely placed, not packed or woven, at the bulbous bottom of the woven bag. In the old, as well as freshly fallen, nests that I have examined this material is not definitely shaped into a circular nest with a depressed center and surrounding walls, but is a formless bed probably designed to prevent the eggs from rolling about and breaking when the nest bag is violently blown about by the strong trade winds of the dry season.

All the nesting material, except that which may be stolen from a neighboring nest, is secured in the immediately adjoining forest, usually within sight of the nest tree.

In well-organized colonies in which the community spirit is developed, the females, when building, usually leave the nest tree to collect material, in a body, and they may be seen gathering it together in the same tree. Material dropped when building is not abandoned, but by a graceful swoop is caught in the air, the retriever returning with it to the nest.

Building birds often take material from another bird's nest either in their own or an adjoining group. Some birds, indeed, are chronic robbers and steal a large part of their material. Slovenly builders are more apt to be robbed than those that leave no loose and tempting ends about their structure. A poor builder is often, therefore, heavily handicapped, for a day's work may be undone in a short time by her thieving neighbors. Birds that do not work continuously

and which consequently leave their nests unprotected are frequently robbed. There is a limit, however, beyond which it does not pay to try to secure material from another bird's nest. Only the looser, partly woven ends may be easily taken. After that the robber may tug and pull, adding her weight to her strength but she gets little or nothing for her labor.

On one occasion a long fiber streaming from the bill of a returning female was grasped by three other females and, becoming entangled in a limb, was lost to all of them. Thoroughly to understand the method by which a nest is constructed would require closer inspection, and from every side, than I have been able to give, even with the aid of a high-power glass. The foundation of the nest is laid by wrapping long rootlets, tendrils, or fiber about the supporting limb until it is well covered. To this is woven additional material forming a flat piece or apron, 10 or 12 inches in length, its extent depending in part on the nature of the attachment. When the supporting limb is more or less horizontal the apron takes shape more readily than when it is perpendicular. Four nests preserved from the tree that was occupied when the laboratory was established, and that subsequently fell, are attached to horizontal limbs and have broad bases or aprons. But the nest tree now occupied, as I have before remarked, offers, as a rule, perpendicular limbs from which an apron is less easily woven. Apparently, therefore, the present tree is less adapted to the needs of *Zarhynchus* than the one that fell, its proximity to the former site having induced the birds to occupy it in spite of its unsuitability. Possibly for this reason the colony does not grow and in time the tree may be abandoned.

Under the normal method of procedure when the apron or base of the nest is finished an opening or hole three or four inches in diameter is made in its lower part and the base of the ring or loop thus formed becomes the lip of the entrance to the nest. This is on one side and usually extends from the lip or rim of the opening to the top, or place of the nest's attachment. The formation of this opening is evidently the most difficult part of nest construction. Its base is usually strengthened by the use of additional material and closer weaving.

In this loop or ring the bird stands working first above and then below. From this stage downward she works inside the lengthening bag which is evidently formed about her body as a mold, until the lower part of the nest is reached when the outline bulges in response to the increased diameter needed for the reception of the true nest. The weaving here is a little closer and the walls of the nest thicker.

Even when the long sack is nearly completed, but is still open below, the builder leaves and enters the nest by way of the door. Entrance is made on the wing with, as the nest is approached, a

slight downward dip followed by an abrupt upward turn which serves to check the speed of the bird's flight. The bird thus flies into its nest without pausing on the threshold. The regularity with which this procedure is followed is an indication of its importance. With its back exposed and head concealed a bird, perched at the nest opening and looking in, would evidently be at the mercy of a foe from without, and this point of exposure is, therefore, passed as quickly as possible. When leaving the nest, however, the position and the conditions are reversed and the bird often perches in its doorway and leisurely surveys the surroundings.

The use of the nest opening from the day it is available trains the bird's sense of location. I have never knowingly seen a bird make the mistake of entering the wrong nest, even when, as is often the case, several are near together. Under normal conditions it is, indeed, rare for a bird to exhibit the slightest hesitation in finding her own doorway. Changes, however, may occur which for a moment tend to confuse it. For example, when the nests swing widely in a high wind not only are they in motion but the actual position of the opening is altered and both factors cause the returning bird to hover for a second or two before slipping into the nest.

A more pronounced case of this nature occurred through the breaking of one of the limbs to which nest No. 5, group 1, 1927, was attached. The nest now half turned around and then spun back, the entrance, therefore, being first on one side then on the other. The owner was at first confused but soon adapted herself to the new situation though she was usually forced to discover the exact position of the nest opening on each return.

Once the bird begins to work inside, little can be seen of her while building until she begins to close the nest at the bottom. Then her bill may be observed actively thrusting and pulling as she hangs head downward within.

There is wide variation in the nest-building ability of different birds. This is probably in part individual, but it is doubtless also a measure of the extent to which their instinct has been developed by experience. Some birds evidently know exactly what they want to do and work rapidly and effectively; others show but little interest in their work and seem at a loss to know how to use the material they have collected.

The members of groups 1 and 2, of the season of 1927, illustrated, respectively, these extremes. The first, as has before been stated, were apparently an organized group of birds that had been associated before, and hence, presumably were more or less experienced. The second group was composed of birds that had not established communal relations and some of which, at least, seemed to be building their first nest.

Group 1 began building on January 8, and for that day my record reads:

Seven females came back from the forest together bringing green tendrils. Some work at old, some at new sites. The first tendril is attached to the limb skillfully and rapidly. It is put over and under, pulled here and poked there. They work feverishly but definitely. Their heads go over a limb with a tendril and then reach under it to get the end and pull it through. No needleworker could proceed with less hesitation.

These birds further showed their energy and earnestness by working in the rain.

On January 9, my journal reads:

A thoroughly rainy morning, with showers and thunder; the whole sky overcast. I see 12 females and 1 male in the field of my 24-power glass. The females are using some fiber and all work furiously, about one half on old sites, the rest on new. There is very little confusion and each bird "sticks to its own knitting." * * * They thrust over and pull under without apparent study and without waiting. Everyone seems to know exactly what she wants to do and goes at it like a master workman absorbed in her task.

The same concentration and effectiveness was shown by this group throughout the period of construction. On January 22, the entry reads:

These birds work whole-heartedly with strict attention to business, rarely coming into contact with one another. Sometimes a head appears through a nest bottom pulling vigorously at a fiber here or poking in a loose end there. Postion is a matter of indifference. They work upside down or right side up; nor do feathers of wings or tail impede their movements. The tail may be bent any way, the wings closed or half-spread. They are intent on only one thing and are not concerned with appearances.

Compare with these extracts the following, describing the nest-building efforts of birds Nos. 1 and 2 of group 2. We have already seen that these birds devoted five days to discussion of the nest location before work actually began. I quote from my notes:

January 24, 7.53 a. m. No. 1 returns with short brown fiber but doesn't seem to know what to do with it. After a half-dazed moment she weaves it into foundation * * *; 9.05, No. 2 returns with a bill full of green tendrils but loses three-fourths of them. No. 1 comes with a bill full of the same kind of material; they fight and she loses all of it.

January 25, 8.14 a. m. No. 1 sits with a straw in her bill, motionless until 8.23 when she uses it.

January 29, 8.05 a. m. No. 2 is still trying to form an opening—the doorway—but it will not take shape. She pokes and pulls and weaves but apparently lacks sufficient experience to succeed. She can weave but she doesn't seem to know what to weave.

January 30, 8.30. No nest in group 2 has a completed opening, and only No. 2 has attempted to make one. All the facts observed suggest that these are young birds making their first attempt at nest building, in which case their instinct must develop slowly with experience.

February 7. No. 1 has broken the bottom of her ring and works with wide-spread feet grasping each end of it. No. 2 has deepened her saucer but has not yet a doorway.

February 10. No. 1 still struggling with her entrance. No. 2 has completed hers and can now get inside the beginning of a bag.

February 14. No. 1 has brought the loose ends of her doorway together and is almost concealed when at work.

In view of these facts it is obvious that the time required to build a nest depends, at least in a measure, on the skill, energy, and persistence of the builder. This statement would call for no qualification if all nests were made to the same model. They vary, however, in length and in amount of lining. It is not impossible that when an undue amount of time has been spent on the earlier stages of a nest it may be brought hastily to completion because of the approaching needs of the female for a receptacle for the eggs. When this need does not force a completion of the task, and consequent closing of the nest bottom, the bag may be continued to the maximum length.

In the absence of examination it is impossible to say exactly how many days are required to finish a nest. One may note the time when the weaving of the bag is finished and its lining begun, but it is not improbable that while the female is laying, or even after she has begun to incubate, she may add to the nest lining.

I have, therefore, accepted as evidence indicating the completion of the nest its occupation at night. This is a definite, observable act and obviously marks an important change in the attitude of the female toward her home. Doubtless at or near this time the eggs are laid.

Throughout the period of building, the females, as before stated, at the end of a day's work accompany the males to the forest. They usually go in a body, the males leading. But there comes a day when the growing attachment of the female for her nest is stronger than the impulse that induces her to follow the male to the roosting place. The conquest of the old habit by the new one is recorded in my entry for February 13, 1927:

To-night for the first time this year the females were seen to enter the nests for the night. There was an unusual number of birds in the colony at 6.10. At about 6.15 they all flew off but returned at 6.18. Again they took flight leaving, however, three females who, after preening, entered nests Nos. 1, 2, and 8 of group 1, respectively.

After this event is inaugurated the gathering in the nest tree of the members of the colony becomes a nightly habit. Even the birds whose nests are not ready for occupation stay in the tree until those whose homes are apparently completed enter them. All sit about industriously preening their plumage in preparation for the night. At about 6.15 the first female enters her nest. She is soon followed by others and by 6.30 all who are to stay have gone to bed and the remainder of the group fly to the forest.

In 1926 this habit was first observed on February 7; in 1927, on February 13. The 1928 colony was too much disturbed to develop it

observably. Recalling that nest building was begun in both the first-named years on January 8, it follows that in these groups of early builders not less than 31 days were required to build the nest bag and line it. I have suggested, however, that with the advance of the season the increased development of the ovaries may induce the builder to finish her work in a shorter time. For example, nest No. 17, of group 2, 1927, begun February 7, was believed to have been completed in 23 days, and nest No. 13 of group 1, 1927, begun February 5, in 25 days.

Completed nests vary from 1 foot and 10 inches to 3 feet and 4 inches in length, but the greatest diameter of all (always in the bulbous base) is 8 inches. Length, as we have seen, may depend on the proximity of the egg-laying period and hence is variable, but the diameter of that part of the bag containing the true nest is fixed by the size of the sitting bird and, therefore, is always essentially the same.

## THE EGGS

The terminal branch to which nest No. 5, of group 1, 1927, was attached was broken, presumably by a strong wind, on the morning of March 7, and the nest fell. It contained two eggs which apparently constitute a full set for the species. One of the eggs was broken, the other measured 33 by 22 millimeters. In color it is pale blue with numerous irregularly shaped brownish-black marks varying in size from a pin point to a currant and clustering most thickly about the larger end. Both eggs contained embryos which I estimated to be about 12 or 13 days old. My records give the following history for this nest: It was begun January 8 and was first slept in February 13. On February 21 the female entered and left the nest 14 times between 8.33 and 9.25 a. m. February 22 she entered and left six times between 8.17 and 9.04. On both days she was accompanied by a male on every journey to and from the nest. The record for the 22d reads: "No. 5 is the only bird of the seven in group 1 who attracts a male, from which I conclude that the other six have laid." February 23 she left the nest only once between 8.17 and 9.04 a. m. and was not accompanied by a male. This evidence suggests that she began to incubate February 23, or 12 days before the nest fell. I shall have something to say about the subsequent activities of No. 5, the owner of this fallen nest.

Incubation in group 1, 1927, was believed to begin on February 18, when the owner of nest No. 2 left her nest at 9.54 and returned at 9.59; these being her only movements during an hour's observation. On March 7, she carried food to the nest. On the basis of these observations the period of incubation in this instance was 17 days. On March 11, this bird was seen removing excreta from the nest.

## THE YOUNG

Long before the eggs hatch the male loses interest in the female and when the young appear they are cared for only by the female. In 1927 young were first noted on March 2 in nest No. 2 of group 1. On March 22 the young in this nest were first heard to call as they were being fed. On the 31st the female fed them by reaching down from the opening without entering the nest, and on April 1 they were seen at the doorway. My observations ended April 2, but it is not probable that the young of this nest took flight before April 5–8.[12] On this assumption the dates of the more important events in the history of this nest are as follows: Nest begun January 8. Female first sleeps in nest February 13 (assumed date of the completion of the nest). Young first noted, March 2. Probable date of flight of young, April 5–8 or 87–90 days from the beginning of the nest.

The period of nearly three months between the beginning of the nest and flight of the young is of course shortened when less time is given to the construction of the nest. For example, nest No. 13, group 1, 1927, which, as stated above, is believed to have been built in 25 days, fell on April 1. It contained one well-grown young which would doubtless have flown in not more than a week or 63 days after the nest was begun.

## NOTES ON THE ACTIONS OF A BIRD THAT LOST HER NEST

As stated above, nest No. 5, group 1, 1927, containing two eggs about 12 days advanced, fell on the morning of March 7. The subsequent behavior of the owner of this nest seems worthy of record. The branch to which the nest was attached broke between 7.30 and 8.30 a. m. when I was in the forest. My observations began at 8.45 when, to quote from my record:

> The female was seen fluttering about the vacancy left by the fall of her home and alighting on the neighboring nests Nos. 4 and 7. Two males and a female joined her and after a few minutes she flew west. At 9.30 she was again looking for her nest but soon departed and did not return for at least an hour, after which I was absent until evening. Between 6.10 and 6.30 p. m. she made four attempts to find her nest, perching on the branch to which it had been attached and examining the entrances to near-by nests; then she flew east to the forest with three other oropendolas.
>
> March 8. A female, after looking about the former postion of nest No. 5, flew to a perch about 20 feet below. Later a female brought new green tendrils to this perch and began to weave. Still later a female perched on the remaining attachment of the fallen No. 5, then at various places above and below and on each side, then flew down and weaved a little where the nest had just been started 20 feet below. This action was interpreted as indicating that the new nest had been started by the bird that had lost her nest and eggs the day before.
>
> March 9. The female believed to be the owner of nest No. 5 worked a little at the nest started yesterday then started a second one on the right fork of the same branch; net result about two square inches on No. 1.

[12] The observations of Dr. Van Tyne indicate that the earlier date is the correct one.

March 11 (absent March 10). No 5 works casually and ineffectively but at three places, all within a few feet of one another.

March 12. No. 5 was not seen.

March 13. No. 5 not seen by me but reported by Mr. W. E. Hastings to have done some work.

March 14. No. 5 not observed.

I find no further reference to this bird in my journal until March 17 when there is the following entry: "No. 5 works at position No. 3 for a few minutes, then disappears. She had made practically no progress since the first day or two." The next and last entry is March 28 when Mr. Hastings reported that a female attended by two males came to the limb on which the new nests had been started and did a few strokes of work.

If I am correct in identifying the bird that began these nests with the one that had lost her nest 20 feet above the new position, and the record of March 8 seems to justify this belief, it appears that after devoting 36 days to nest building and approximately 12 to incubation she could, after one day's manifestation of interest in the lost nest, return to that part of her annual cycle, which in the normal process of development had been reached when she first began to nest, 58 days prior to her loss. Its promptings, however, were not sufficiently strong and definite to enable her to complete a new nest.

## ENEMIES

Aside from the parasitic blackbird, *Cassidix*, and flycatcher, *Legatus*, two other birds were found to attack the oropendola colony on Barro Colorado. Only one of these is diurnal, nevertheless the males are constantly on guard. It is, indeed, their duty to act as watchmen of the colony. While building, the females' attention is of necessity concentrated on their work and until they begin to weave inside the structure they are exposed to attack from birds of prey. The males, however, in spite of their almost constant wooing, are ever on guard and when a hawk is seen they are the first to utter the rapid, cackling alarm note, the females joining them in calling on certain occasions. This is a signal for the whole colony to dive precipitately into the lower growth of the adjoining forest.

Turkey buzzards do not, as a rule, evoke this call and generally the white snake-eating hawk (*Leucopternis ghiesbrechti*), a pair of which lived near the laboratory, was permitted to pass unchallenged. But at times even the appearance of these birds, more particularly the latter, was the occasion for an outcry and the accompanying downward rush to cover. Rarely a low-flying airplane created alarm. Often the warning cry is given without apparent reason but its cause may have been clear to the birds if unseen by me. Possibly also it may have shades of meaning to which human ears are deaf.

The response of the oropendolas to this note is variable. At times they act as one bird and plunge from their nests or perches into the forest. I have even seen a bird when flying toward her nest dodge abruptly downward in the air when hearing the alarm. On the other hand, while it evidently puts the birds on their guard, they may not move when hearing it.

The significance of this call is understood not only by oropendolas but obviously by other species. On February 8, 1926, five toucans (three *Pteroglossus*, two *Rhamphastos piscivorus*) and two caciques (*Cacicus vitellinus*) that were in the nest tree dived with the oropendolas when the alarm was given. On the following day it induced even a trespassing *Cassidix* to seek safety with her intended victims from a supposed common enemy.

The need for a lookout and for prompt obedience to this danger signal was tragically illustrated on February 12, 1927. At noon on that day Mr. Maunsell S. Crosby, who was standing near the nest tree watching the oropendolas at work, saw an eagle hawk (*Spizastur melanoleucus*) drop from the sky, strike an oropendola that was working on her nest and bear her to a neighboring branch. The hawk, which was identified by Mr. Ludlow Griscom, was still standing on its victim when a few moments later, attracted by the unusual outcry, I reached the tree. It soon flew off with its prey to the forest. This event caused tremendous excitement among the oropendolas, their united cries of alarm producing the effect of a loud chorus. They all left the tree and for the remainder of the day the colony was completely disorganized.

The following day the effects of this catastrophe were still evident in the nervousness of the birds and the frequency with which the alarm call was uttered. Normally this call may be heard three or four times during a morning, but during two hours on the morning of February 13 it was given at 8.50, 8.51, 8.55, 9.04, 9.07, 9.10, 9.12, 9.22, 9.40, 10.12, 10.15, 10.26, 10.44, and 10.50, a total of 14 times in two hours. Beyond two buzzards that flew over at 9.10 and 10.44, respectively, no cause for alarm was seen by me during this period. The first seven times the alarm was sounded all the birds responded promptly, diving to the protection of the lower growth. Later their reaction was not so keen and on three out of seven signals they did not respond.

The incident illustrates the exposure to attack by a predatory bird of an oropendola working outside her nest, the need for a guard, the importance of prompt obedience to his warning, of the quickening of reactions through experience, and of their decline after frequent call has been made upon them.

It might be imagined that the birds in their long nest bags swinging from the tips of slender branches were immune from attack.

They can doubtless be reached by tree snakes, though I have no evidence of their being preyed on by these, or by other reptiles. Possibly marmosets may be able to approach them, but we have never known them to do so. Furthermore, any diurnal enemy would doubtless be subjected to attack from the sharp, strong bill of the female, and perhaps also of the male *Zarhynchus*. It is, however, a nocturnal winged foe that proves to be one of the most serious enemies of the oropendola. This statement is based on observations made on group 1, 1928, and recorded in my journal for January 25, as follows:

> Seven-thirty a. m. Some mishap has befallen group 1 (containing 8 nests) during the night. Nest No. 3 is hanging upwind across the lower part of No. 4, and has a large, round hole in its bottom, evidently made from without. No. 5 has a similar opening. Nos. 2 and 4 each have a small round hole in the side near the bottom. I showed these nests to Donato, who at once said: "El buho" (local name for *Pulsatrix perspicillata*) and added that early one morning in the preceding year he had seen an owl fly from its perch in the dead tree adjoining the sand box tree and pick at the oropendola nests. Certainly whatever did this work had wings.

The owl named is seen or heard about the clearing nightly. Donato, our resident factotum, is a careful observer, and it is probable that his identification of the marauder is correct. All the nests mentioned were begun on January 2 and it is possible may have contained eggs though I had no record of the birds' sleeping in their homes. The owners of Nos. 2 and 5 returned to their homes and were evidently incubating as late as February 3.

Apparently the attack of the owl or owls created a condition which made the remaining birds in the group more susceptible to persecution by *Legatus* and eventually the whole group site was abandoned. On former occasions I had seen holes an inch and a half in diameter at the side of the nest bag about on a level with the nest and supposed that they were made by the owner; but if they are made by the foot of an owl reaching in while clinging to the nest, it is evident that the home of *Zarhynchus* is far from impregnable.

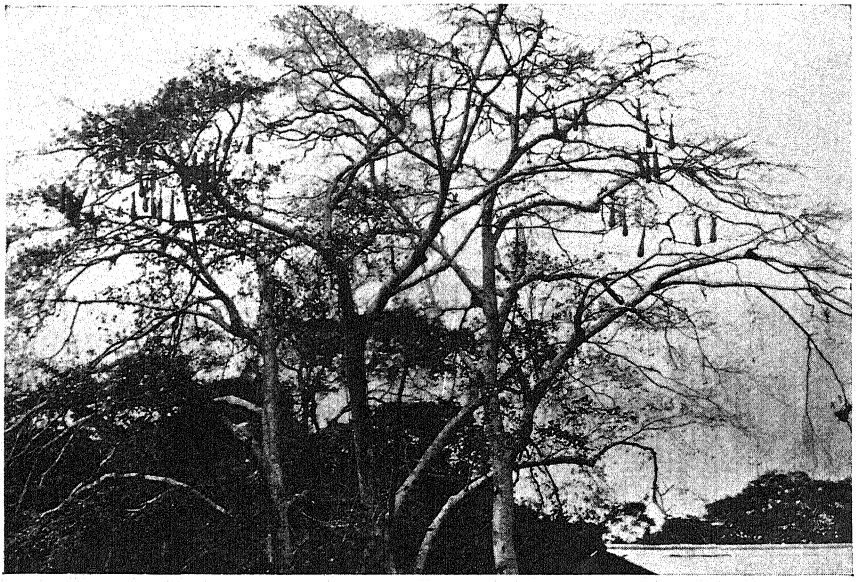
## PARASITIC BIRDS

*Zarhynchus*, while nesting, is parasitized by two other birds, one of which, in effect a large cowbird (*Cassidix*), visits the colony from time to time to deposit its eggs, while the other, a flycatcher (*Legatus*), is a permanent resident who in seeking to gain possession of an oropendola nest for its own uses becomes a community affliction of the first magnitude.

*Cassidix oryzivora*.—It has long been known that *Cassidix oryzivora* is parasitic on certain members of the oropendola-cacique



The sand-box tree with nests of *Zarhynchus* from near the bottom of the slope below the laboratory. The tree was 132 feet in height; note the figure of a man at its base

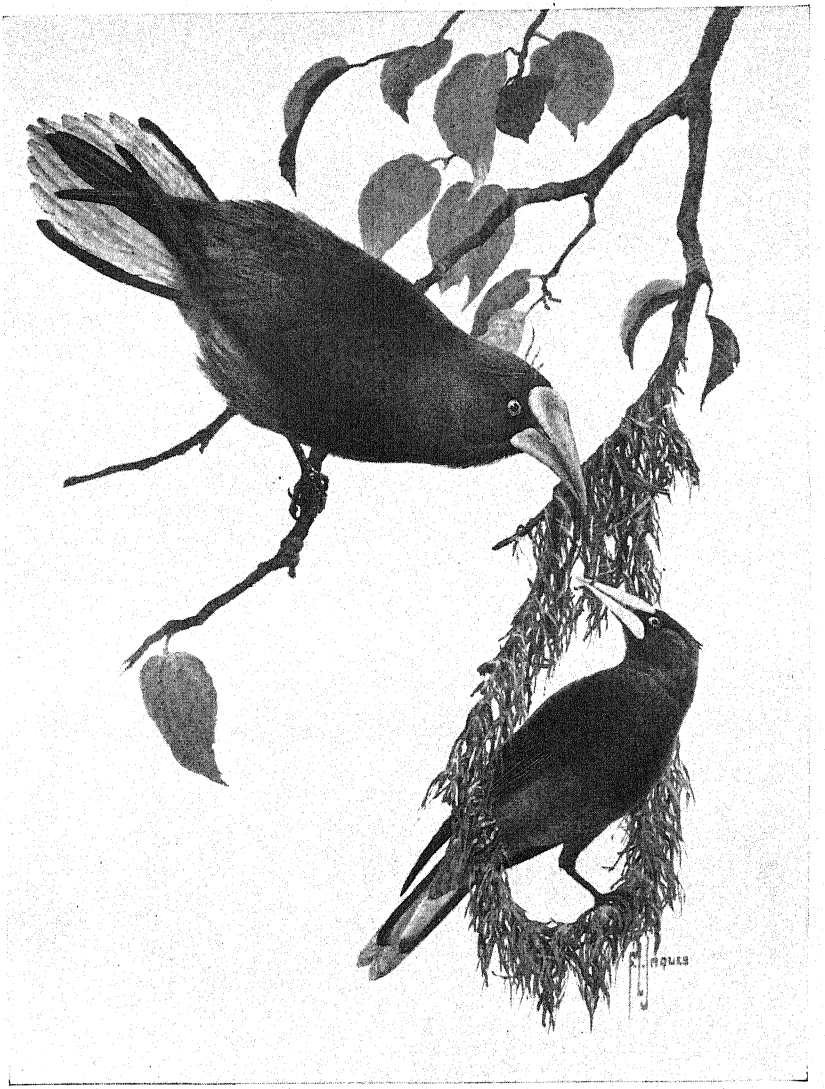


1



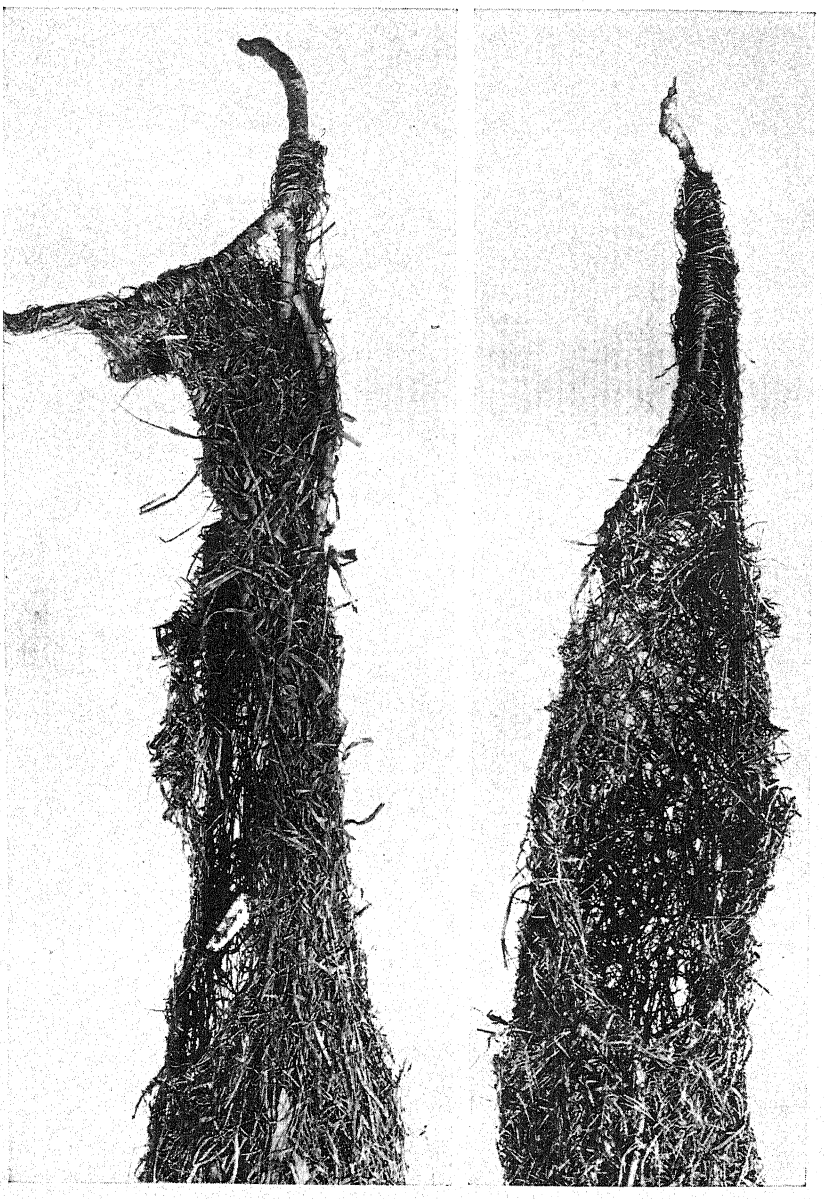
2

1. The *Zarhynchus* colony in the sand-box tree, from the point at which, with the aid of a 24-power binocular, most of the observations on which this paper is based were made. The roof of the main laboratory building appears in the right foreground. Photographed with a 14-inch lens. 2. Eight females of *Zarhynchus* beginning to build their nests in the sand-box tree. Group 1 of the colony of 1927, January 8. An old nest hangs at the left of those under construction. (See p. 438.) Photographed with a 14-inch lens, from the laboratory level



THE COURTSHIP OF ZARHYNCHUS

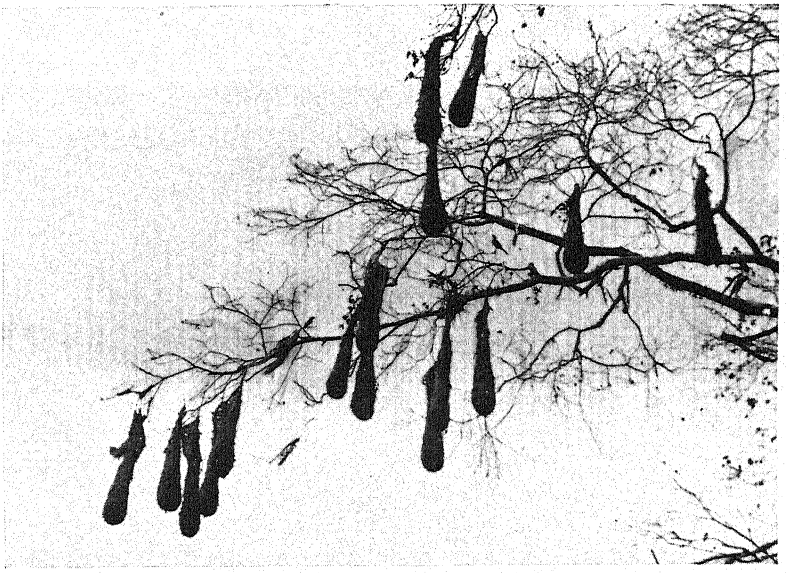
The male (upper figure), with dorsal feathers displayed, tail partly opened, flank feathers slightly raised and crown plumes spread laterally, is addressing the female. She ignores his presence and proceeds with the building of her nest which has reached the loop stage. From a drawing by F. L. Jaques. (About one-fourth natural size.)



Nests of *Zarhynchus* showing openings and method of attachment to site. The nest at the left is from the tree that fell shortly after the laboratory clearing was made; the one at the right is from the sand-box tree. The former is believed to have been better adapted to the builders' needs



1



2

1, *Zarhynchus* nest in the early stage of construction at which the loop is made. (See also pl. 3); 2, A portion of the *Zarhynchus* colony of 1927 in the sand-box tree. Note the pair of *Legatus albicollis* at each side of the central group of nests. These birds appeared and harried the nest owners persistently during the remainder of the nesting season. (See pl. 8.) Photographed with a 23-inch lens from the laboratory level



1

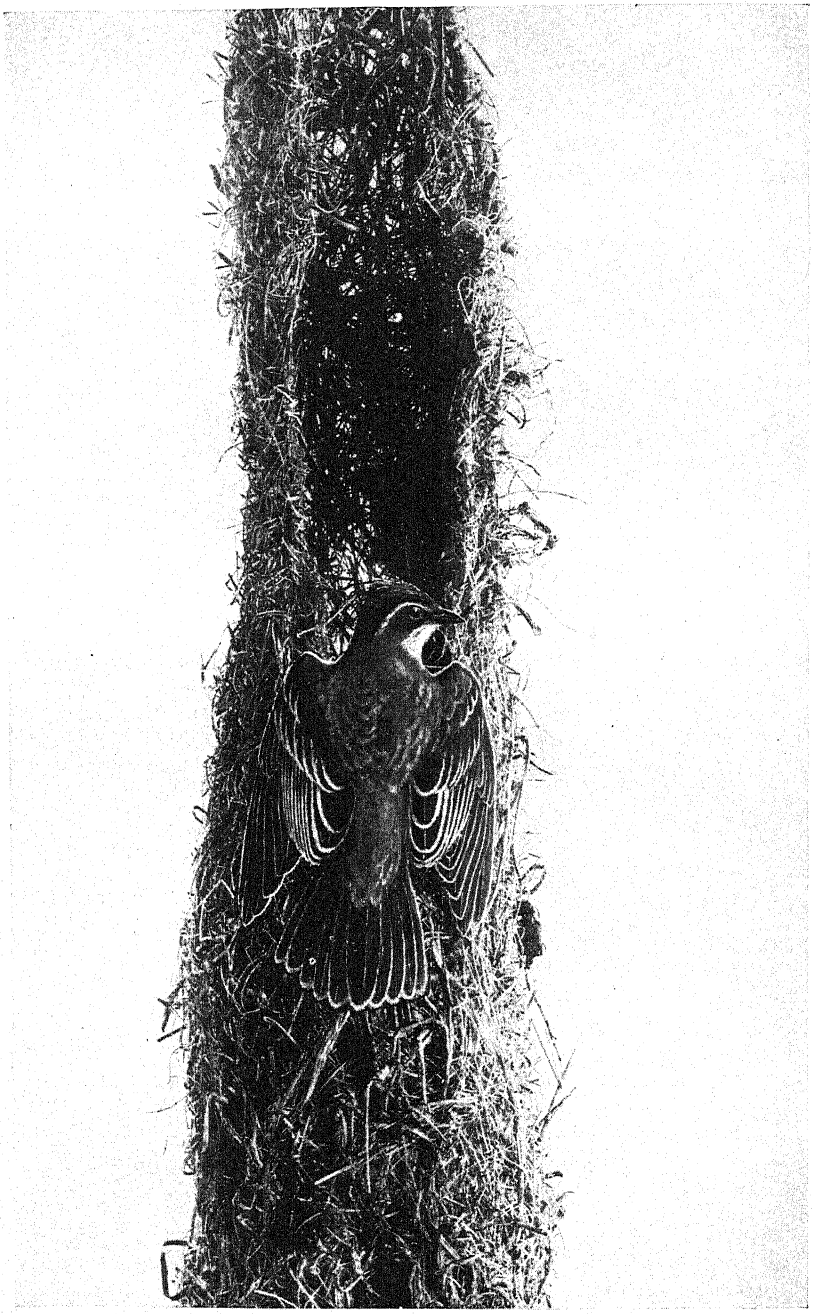


2

1. *Zarhynchus* nest bags in the sand-box tree swaying in a fresh breeze. Their motion illustrates the necessity for the soft nesting material at the bottom of the bag forming the true nest. Photographed from the laboratory level, with a 14-inch lens. 2. Fallen nest of *Zarhynchus* cut open at the bottom to show the single nestling it contained, nearly ready to fly. Note the light (yellow) marks on the forehead at each side of the base of the bill. April 1, 1927



Nest bag of *Zarhynchus* to show opening at the nest level, made, apparently, by the owl, *Pulsatrix perspicillata*, to secure the contents of the nest



*Legatus albicollis* inspecting a nest of *Zarhynchus wagleri*, with a view to occupancy. The figure of *Legatus* was drawn by F. L. Jaques on a photograph of the nest of *Zarhynchus*. (Slightly less than one-half natural size)

group.[13] Possibly, since their ranges are conterminous, it may prove to be parasitic upon all of them. Whether it also parasitizes other species does not appear to be known.

To our scanty knowledge of the relations between this species and its hosts I append a summary of my observations on Barro Colorado.

In 1926, *Cassidix* was first observed on January 28; in 1927, on January 19, and in 1928, on January 11, or respectively 20, 11 and 9 days after the beginning of nest building. In 1926 earlier visits to the oropendola colony may have been overlooked for my attention was not then focused on these birds. From the dates mentioned until that time in each year when my observations ended, *Cassidix* was frequently seen in the *Zarhynchus* nest tree. For some periods my records show daily visits and at times several visits each day.

A female is first recorded as entering a nest in 1926 on February 4; in 1927, in spite of frequent attempts, one was not seen to succeed until February 25; and in 1928, on January 18. Since on the last-named date the nest entered was not completed, the bird was evidently making a reconnaissance. As most of my observations were made in the morning the greater number of my records of the presence of *Cassidix* in the oropendola tree were made before noon. The earliest is at 7.40 a. m. but the species was seen in the colony as late as 6.30 p. m.

The birds seemed to come from a distance and usually alighted at or near the top of the sand-box tree. Here they would remain for several minutes and then pass from limb to limb and along the limbs toward the *Zarhynchus* nests selecting, as a rule, those finished or most nearly completed. The earlier visits of *Cassidix* appeared to be for inspection and when attacked by *Zarhynchus* they quickly retreated and soon took flight. Later, when their needs were doubtless more pressing, they persisted in their attempts to enter the oropendola nests sometimes succeeding in spite of the combined efforts of several oropendolas and the resident pair of *Legatus* to prevent them. On leaving the tree they usually started on an extended flight, sometimes over the lake, that soon carried them out of sight.

Visits from single birds or twos was the rule, more rarely three were observed together and on February 8, 1927, five females, the greatest number seen together, perched in the tree top. Several at-

[13] The recorded species and localities are as follows:

*Ostinops decumanus.*—Southern Brazil, GOELDI, 1894, "Aves do Brazil," p. 284; 1897, Ibis, p. 364. British Guiana, 1896, LLOYD, Timehri, N. S., X, p. 37.

*Gymnostinops montezumae.*—Costa Rica, CRANDALL, 1914, Zoologica, I, pp. 339, 341.

*Zarhynchus wagleri wagleri.*—Costa Rica, CRANDALL, 1914, Zoologica, pp. 338, 342.

*Cacicus cela.*—Para, Brazil, KUSHEL, 1896, Ibis, p. 585; 1897, J. F. O., p. 168. GOELDI, 1897, Ibis, p. 364. British Guiana, LLOYD, 1897, Timehri, N. S., XI, p. 5.

*Cacicus haemorrhous.*—British Guiana, LLOYD, 1897, Timehri, N. S., XI, p. 5.

tempts were made by single birds of this group to enter nests but they were prevented by *Zarhynchus*. Finally all left together in the usual long flight.

The male *Cassidix* was recorded on only three occasions, January 19, 1927, February 10 and 19, 1928. On the first-named date a male was accompanied by three females before which he slightly expanded his ruff. On February 10 there were also three females with a single male. On February 19 there was only one female with a single male. The actions of these birds seemed to indicate that more than a passing relation existed between them and I quote my description of it:

> Seven-thirty a. m. A male and female *Cassidix* in the top of the sand-box tree. The male's plumage glistens brightly and he is conspicuously the larger of the two. Some minutes after I discovered them the female started alone, circled the tree twice in a rising spiral flight, then headed east. The male continued preening. In about three-quarters of a minute a female alighted near the male and half a minute later started due east. He followed. Assuming that there was only one female, did she circle on her first flight while awaiting for the male to follow? Did she return because he did not?

*Cassidix* is obviously recognized as a common enemy not only when she seeks to enter a nest, but when, early in the nesting season, she enters the nest tree. Not alone the bird whose nest is threatened but other birds in the same group, and also from other groups, join in attacking her; while *Legatus* assails at times with more zeal than *Zarhynchus*. An incident illustrating these facts is recorded in my journal for February 7, 1926:

> At 4 p. m. a female *Cassidix* tried to enter several nests but so clumsily that before she discovered the combination she was driven off by a combined attack of several female oropendolas. Evidently, they recognized her as an enemy and united in communal defence without regard to the nest threatened. I saw a female from group 1 fly to the protection of a nest in group 3. *Cassidix* retreated to another part of the tree where she was not molested. Within 10 minutes she made another attempt but was again defeated. Even two *Legatus* seemed to recognize this visitor as undesirable and with fluttering wings flew excitedly about her. At last she left the tree, a solitary outcast, followed by half a dozen oropendolas to the boundary of their territory.

Several entries describe the aggressiveness of *Cassidix*. Thus, February 15, 1926, at 10.37 a. m.: "*Cassidix* tries to enter a nest in group 2 but is mobbed and driven off; she fights back" and at 10.50 the entry reads: "*Cassidix* tries to enter group 3, is driven off by *Zarhynchus;* fights them in the air; *Legatus* joins in the attack as *Cassidix* is routed." And on February 25, 1927, at noon: "*Cassidix* enters two nests, staying 15 to 30 seconds in each. Two *Zarhynchus*, and both *Legatus* drive her off repeatedly, but she fights them as though she were defending her own nest."

A curious performance is recorded at 8.34 a. m. on February 13, 1927, when my notes read: "A female *Cassidix* displays before or addresses a female *Zarhynchus* on a new nest at the left of No. 5,

group 2. She draws herself up to full height, slightly expands her ruffs, with bill down then curls head downward until bill touches lower breast. *Zarhynchus* meanwhile concerned and whines slightly. The performance is repeated." Less marked was the action of two females who, on February 18, 1928, posed on a limb in the sand-box tree with their bills pointed upward, like boat-tail grackles.

The probability that *Cassidix* is aware of the conditions existing in a *Zarhynchus* colony is indicated by the fact that after the nesting colony of 1928 was abandoned *Cassidix* was not seen in it. On February 26 my journal reads: "Apparently not an oropendola left in the tree." On the following date this entry appears: "*Cassidix* in group 2 examines and enters nearly every nest, its longest stay being three seconds. It was opposed only by male and female *Legatus*. No *Zarhynchus* in the tree." This is my last record of *Cassidix* for the season, though observations were continued until April 1.

In these observations the long flights, the visits of inspection and the forced entrance into nests are of interest. If *Cassidix* is parasitic only on species of the oropendola-cacique group it must cover comparatively great distances in its search for a host. In my experience the nesting places of colonial birds of the same species are not close together. On Barro Colorado, for example, as we have seen, only three colonies of *Zarhynchus* are known. *Cassidix*, therefore, must not only cover much territory but presumably she must be aware of the stage of the nesting season which has been reached by her prospective hosts. It would be useless to deposit eggs in the nests of birds not prepared to incubate them. Unless, therefore, *Cassidix* can control the development of her ovaries she must either waste eggs or know where to place them to advantage.

*Legatus albicollis.*—An unexpected result of my studies of *Zarhynchus* is the discovery that it is parasitized by *Legatus albicollis*. In each of the three nesting seasons devoted to the oropendolas a pair of these flycatchers made their home in the nest tree and constantly harried the oropendolas for the purpose of gaining possession of one or more of their nests. *Legatus* was also found in the two other known nesting colonies of *Zarhynchus* on Barro Colorado, and its association with *Zarhynchus*, at least on this island, appears therefore to be habitual. It will be interesting to learn whether it parasitizes other oropendolas. It arrives at about the time or even before the oropendola nests are completed and remains throughout their nesting season. In the morning it appears in the nest tree within a minute or two after the first *Zarhynchus* call is heard and it remains there until evening. It was never seen to feed from or near the nest tree but at intervals of an hour or more it darted to the adjoining forest evidently for food, but was rarely absent more than three minutes.

Not less than 90 per cent of its time during the day was devoted to calling. No bird I have ever heard approaches *Legatus* in the continuity with which its notes are uttered. Morning, noon, or afternoon it was the exception, when consciously listening, not to hear the voice of *Legatus*. Both sexes call, but the male seems to be the more vociferous and, when incubating, the female is apparently silent.

Their usual note is "pee-ee" with a suggestion of the phoebe's (*Sayornis phoebe*) tons. To this is often added "teedle-dee-dee." There is also a "twee-twee-twee-twee," etc., uttered continuously, with closed bill, for as much as a minute. The female frequently uttered this note while the male called "pee-ee, teedle-dee-dee." During attacks on *Zarhynchus* both sexes utter an excited, reedy twittering and chattering.

*Legatus* evidently considers itself a member of the *Zarhynchus* colony and, although its motives are unworthy, it often attacks *Cassidix* more zealously than does the owner of the nest which that bird seeks to enter.

Since it is evident that *Legatus* plays an important part in the nest life of *Zarhynchus* I give the more significant of my observations concerning it as a contribution to our knowledge of their relationships, which, as will be seen, are as yet by no means clearly understood. In 1926 *Legatus* was first noted in the nest tree on January 29, 21 days after nest building began, but it was not until February 9 that I realized the object of its presence. I quote from my records of that date:

> It is evident that *Legatus* is interested in the *Zarhynchus* nests. Two of these birds have attached a claim to two detached nests at the left side of the tree and fiercely attack their owners, often driving them from their own doorstep. The poor oropendola sits humbly in the protection of the leaves waiting for a chance to enter her own home and in spite of the swinging onslaughts of *Legatus* finally succeeds by a dash. I have not seen *Legatus* enter either nest but they examine the opening and perch at the point to which the nest is woven with an unmistakable air of proprietorship. What is their object?

These birds were under observation until February 20 when I left the island for the season. They eventually focused their attention on one of the two nests, called in my notes No. 1. On February 17 for the first time one entered this nest remaining three seconds, to which *Zarhynchus* still asserted ownership by also entering for the night, both *Legatus* then going to the forest. On the 19th at 12.05, after *Zarhynchus* left the nest, one *Legatus* entered and remained for five or six seconds. Both the flycatchers were about the nest the greater part of the day; at 3.25 *Zarhynchus* tried to enter it but was driven off and at 5.20 *Legatus* came from the forest and with almost no hesitation flew directly into the nest, remaining for 10 or 12 seconds. At 4.40 the flycatcher was in the nest for 15 seconds

and *Zarhynchus* had not appeared. On February 20 at 7.35 a. m. *Legatus* entered the nest and remained for 25 seconds. Three minutes later *Zarhynchus* entered the second nest without protest, but at 7.45 when a *Zarhynchus* came to No. 1 it was driven away by *Legatus*. Thereafter, during the day, *Legatus* entered nest No. 1 frequently and my notes say, "It seems apparent that they now have possession of No. 1." Here, as above stated, my observations ended but I left a note asking Dr. J. Van Tyne, who reached the island February 28, to continue them. He reports that the activities of *Legatus* did not, apparently, lead to definite results.

In 1927 *Legatus* was first noted January 31 (23 days after nest building began). For the first few days the bird perched in the top of the tree frequently uttering its "pee-ee" note. I was now absent for three days, returning February 6 when there were two birds present. One of them dove at nests 1 and 3 of group 1, and attacked one of their owners. From that date until the end of my observations on April 1, there were few moments during the day when these birds were not present in the nest tree. Their notes were heard almost constantly and the greater part of their time was devoted to attacks on *Zarhynchus* and to examining its nests. These attentions were distributed throughout the colony, and were not concentrated on any one nest or bird. At the end of the period of observation the birds seemed to be no further advanced toward acquiring a home than they were at the opening of the season. Dr. J. Van Tyne, who reached the island February 24 and remained until August 21, was good enough to keep these birds under observation. His notes in full are given on page 354. They show that *Legatus* was present until April 26 (when apparently because of heavy rains the oropendolas abandoned the colony) but that it was as "ineffectual as ever."

Several entries in my journal for 1927 may be quoted:

February 26. *Legatus* attacks any bird entering group 1, but seems still to prefer No. 1. Both go to the entrance, drop and partly spread their wings, lower their heads and turn half right then half left with a queer little bow; a singular, self-conscious kind of performance.

March 11. *Legatus* shows no decrease in energy or interest. It is now chiefly in the west end of group 2, calling and fluttering excitedly at nest entrances.

March 24. *Legatus* seems to be more aggressive and active. They attack almost any *Zarhynchus* and swing from group 1 to group 2 and back. No. 12 receives most of their attention but no choice has been made. There are two deserted nests in group 1 but they probably contain eggs. But doubtless those in group 2 do also.

As a rule *Zarhynchus* avoids *Legatus*, as already described, but when the small bird's attacks exasperate it beyond the limit of endurance it assumes the aggressive. The record for March 6, 1927, reads: "A female *Zarhynchus* pursues *Legatus* around and around

the tree and is herself pursued by the other *Legatus*." On March 12 and 15 similar incidents were noticed, and from the record of March 22 I quote:

While *Legatus* was perched at the entrance to a *Zarhynchus* nest the owner popped out and pursued her persistently, following her at least 10 times around through the tree and on two wide circles over the forest. Meanwhile the other *Legatus* pursued the attacker.

In 1928 a single *Legatus*, presumably a male, was heard calling from the nest tree at 6.30 on the morning of January 16 (14 days after the nest building began). After calling for about two hours from the upper part of the tree (not near the nests) he disappeared. At 5 p. m. he called again for a few times and departed. Probably the same bird was present on the 17th and 19th. On the latter date my entry reads:

Only one *Legatus* seen. He sits in the top of the oropendola tree calling, perhaps for a mate; but already shows a sense of proprietorship by chasing *Cassidix*.

On January 20 a second bird, probably a female, appeared. Three days later I wrote:

*Legatus* is now in full swing in group 1. Both birds attack every *Zarhynchus*, indiscriminately, males as well as females. The males are not even permitted to court but are driven from their perches by the wasp-like attack of these two relentless little birds, who one after the other dart at them and swing upward to dart again. The females are similarly annoyed both when they enter and leave the nest and also in the air, as they approach it. Often they are prevented from entering and take refuge among nearby leaves to await an opportunity to slip in unnoticed. The life of the whole group is being disorganized by the persistent and constant annoyance of these two irritating flycatchers. They have apparently chosen No. 6 for their especial victim but they by no means restrict their attention to her.

On January 28 one *Legatus* was seen sitting at the entrance to nest No. 5, which, although it had been attacked by an owl on the night of January 25, as before described, was still occupied by its owner. On February 1, No. 5 was entered by *Cassidix*. The bird remained for four seconds, *Legatus* alone protesting.

Between February 1 and 7 the record for *Legatus* is summed up in the entry for the 4th which reads: "*Legatus* continues its endless peedle-dee-deeing but seems to get nowhere." Occasionally it chased a *Zarhynchus*. On the last-named date I record:

*Legatus* now worries the owners of Nos. 1 and 2, group 1. The latter chased one of the flycatchers out of the tree this morning. If they want a nest why do they not take either No. 3 or No. 4 which are deserted but look in good condition? This afternoon the Legatus which I believe to be the female entered No. 1 and remained for 18 seconds.

There were no further developments until February 11. My record for that day is as follows:

It looks as though the *Legatus* puzzle had finally solved itself. At 12.45 I chanced to see *Legatus* enter No. 5, group 1. On emerging, after four or five

seconds, she left the tree and at the end of about two minutes returned and entered No. 5 again. Having my glass now turned on the nest I saw that she carried something in her bill. Moving with my 24-power glass to the end of the laboratory I saw, when some two minutes later she reëntered the nest, that she carried what appeared to be a small bit of a brown leaf. She entered the nest so quickly, however, that I could not be sure of the exact nature of her burden, but two visits later she brought an entire leaf perhaps three-fourths of an inch long. It seemed evident, therefore that she was building a nest. I say "she" for the one that remained outside, perching within a few inches of the nest opening, called constantly and greeted the builder with vociferous, excited twitterings on her return. During the succeeding 20 minutes 10 visits were made by the female, each time with building material. Only twice during the succeeding four hours did *Zarhynchus* appear. Once a female swept down as the female *Legatus* was about to enter, and at 3.55, while the female *Legatus* was in the nest and the male at its door, a *Zarhynchus* came with the apparent intention of entering but she retreated quickly before the fury of the *Legatus* attack. Half a minute later the female flycatcher continued her work.

Thereafter *Legatus* was left in undisturbed possession of this nest. It may be noted that my records now showed this nest to have been visited by *Cassidix*, attacked by owls and claimed by *Legatus*.

For the succeeding seven days *Legatus* continued peacefully to occupy, or at least frequent, this nest No. 5 of group 1, but February 19, to my surprise, both birds were seen fiercely attacking nests Nos. 1 and 2 in group 2, fully 40 feet above No. 5 of group 1. They perched at the entrance to the nest, fluttered excitedly and peered within just as though they were prospecting for a home. At 6 p. m. one was seen sitting within No. 5, its head only showing at the entrance.

The combined attacks of *Legatus*, and of what I believe to be *Pulsatrix*, finally resulted in the complete disorganization and abandonment of the *Zarhynchus* colony, and on February 26 I write "apparently not an oropendola left in the tree. *Legatus* having no fresh fields to conquer may now devote herself to her own affairs."

From February 19 to March 4 *Legatus* was heard calling with undiminished energy, but I saw only what I believe to be the male bird and assumed that his mate was sitting and would at any day produce a brood in nest No. 5. On March 4 the female was seen preening near the male but I did not succeed in tracing her to a nest, and on March 5 it appeared that they were interested in nest No. 2 of group 2, and apparently had deserted No. 5 of group 1, in which they had built a nest. No evidences of building in No. 2 were observed but the evidence indicated that on March 12 she was incubating in that nest. My record follows:

8 a. m. Female *Legatus* perches near the entrance to No. 2, group 2, the male nearby. She preens her plumage disclosing a wide parting from sternum to vent, which bespeaks the sitting bird, then enters the nest.

March 15, I record:

7.30 a. m. A male *Zarhynchus* alights on nest next to that of *Legatus*. They both attack with frenzy and finally drive him off. Then the male *Legatus*

looks in the nest fluttering and calling excitedly and after he repeats this performance she enters. 5.15 p. m. Both *Legatus* sit near nest preening. She flies in and remains. He continues to call. Have not heard her call since she began to nest.

From this date until March 24, the life of the two flycatchers centered about this nest which the female was seen to enter almost daily.

On the night of the 23d the twig to which nest No. 1 of group 2 was attached broke and the nest fell. It was found to have the round hole in the side at the inner nest level that I associate with nocturnal attack and, since there was not sufficient wind to account for the fall of the nest, I attribute the mishap to the weight and movements of the marauding visitor. There was nothing in the nest when, early on the morning of the 24th, I picked it up beneath the tree.

This nest hung with, and almost touched, No. 2 occupied by *Legatus*. The latter nest was also seen to be penetrated by a hole similar to that in No. 1. My records for the day read in part:

7.30–8 a. m. *Legatus*, male, sits above nest calling as vigorously as in January. The female appears, and preens showing the abdominal parting. The male flutters excitedly at the mouth of the nest but does not enter. He returns to a calling perch and the female enters the nest. All perfectly regular but where are the young?

Later in the forenoon I wrote:

Male and female *Legatus* perched near nest. Both call "tweet-tweet," etc. This is the first time I had seen her call since she began incubating. . . . Female *Legatus* again near nest preening. She is off the nest more to-day than at any previous time during incubation. Twice the male has attacked her standing over her with fluttering wings while she with belly up hangs below him. I saw no blow struck but the attitudes were those of offense and defense. After a few seconds both flew off.

At 11 a. m. the female entered the nest. March 25 *Legatus* called as usual. At 4 p. m. a male *Zarhynchus* alighted on their nest. *Legatus* attacked vigorously but for the first time under this threat no female appeared.

*Legatus* continued to call loudly and persistently on the 25th and 26th but no female was seen. On the 28th, however, one appeared. My record reads:

*Legatus* has not called in vain. A female of his species was present this morning and the evidence indicates that she was not the bird that occupied and was apparently nesting in No. 2. He chases her and is, I think, trying to show her one of the group of four nests in group 2. She seems to be in fresher, less worn plumage than the supposedly missing female, and when preening, which she does only occasionally, the feathers do not part widely in the center of the abdomen. She perched for a moment on No. 2 but she did not enter.

March 29, 30, 31, *Legatus* called with all the vigor of the early season but no female appeared. At this point my record for the season ends.

I can present only a theoretical interpretation of the actions of this pair of birds. To me they indicate that the contents of their nest (No. 2, Group 2) having been destroyed by night attack, the female deserted. The male then attracted the attention of another female but did not succeed in winning her as a mate.

## ASSOCIATED SPECIES

The sand-box tree in which the oropendolas nest forms an attractive and advantageous perch, particularly for birds that cross the clearing. During the period covered by these observations I have seen slightly over 50 species of birds in it. Four of these species, in addition to *Zarhynchus* and *Legatus*, nest in the tree; they are the violet-throated humming bird (*Anthracothorax violaceicollis*), the Colombian flycatcher (*Myiozetetes texensis columbianus*), Natterer's cotinga (*Cotinga nattereri*), and the blue tanager (*Thraupis cana*). Of all the birds seen in the tree, only six appear to have direct association with *Zarhynchus*. They are a cowbird (*Cassidix oryzivora*), a flycatcher (*Legatus albicollis*), a hawk (*Spizastur melanoleucus*), an owl (*Pulsatrix perspicillata*), a cacique (*Cacicus vitellinus*) and a humming bird (*Anthracothorax nigricollis*).

The first two are parasitic, the second two, predaceous. Their observed relations to *Zarhynchus* have already been described under the section devoted to the enemies of *Zarhynchus*. The relations of the remaining two I will speak of here.

*Cacicus vitellinus*.—From the beginning to the end of the nesting season, as I have observed it, usually one cacique is present in the nest tree acting as though it were a member of the colony. Rarely two males were seen, and on February 16 two males and two females were in the tree at the same time. One male, however, is the normal *Cacicus* representative. This bird often arrives as soon as the first *Zarhynchus*, and it, or another, may be in the tree the greater part of the day. It makes no attempt to associate closely with *Zarhynchus* and does not perch very near the nests, its chief activity being the delivery of its calls. While bearing a general resemblance to those of *Zarhynchus* the notes of *Cacicus* are more varied, more musical and louder, and they are uttered more continuously and more insistently, at times for an hour or more without ceasing. In view of the fact that no other individual of its own species is in the tree or apparently near, and that the bird addresses only a general and unresponsive audience, its energy and persistence are inexplicable. At its maximum the delivery of its notes is accompanied by an interesting display in which the wing tips are crossed beneath the tail and behind the feet, the yellow rump feathers fluffed and expanded, while the wings and tail are violently trembled. This continues for several minutes as the bird calls loudly. Occasionally a male

*Zarhynchus* drives the too willing performer from his perch but beyond this no attention is paid to him. According to Jewell, as reported by Stone,[14] *Cacicus* nests in the Canal Zone in March. One might imagine, therefore, that the male or males that devote themselves so earnestly to the *Zarhynchus* colony might find more appreciative listeners in the females of their own species.

*Anthracothorax nigricollis.*—Nesting in the sand-box tree evidently gives the black-throated hummer a sense of proprietorship which leads it to attack nearly every trespassing species including *Zarhynchus* and its enemy *Cassidix*. The bird, therefore, plays some part in the nest life of the oropendola while the regularity of its return to the nest tree affords additional evidenc eof marked periodicity and localization in tropical birds.

On January 16, 1926, a black-throated humming bird was discovered on the eastern side of the sand-box tree building its nest near the tip of an absolutely bare limb at least 25 feet from the nearest leaf. There was not a more expose site in the tree. From this point it attacked birds trespassing within its territory with a dash and courage which promptly put them to flight. Oropendolas were frequently followed to their nesting quarters and sometimes driven from the tree. So effective and persistent were the bird's assaults it seemed not improbable that if they had been made before the oropendolas had begun to build they might have prevented them from settling in the tree.

On only one occasion did the bird retreat before a trespassing species, this was a white snake-hawk (*Leucopternis ghiesbrechti*) which in one instance perched within a few feet of the hummer which promptly took flight. On the other hand a bucco (*Bucco subtectus*) was permitted to sit for some time near the hummer's nest without molestation. The nest was apparently completed about January 20, and the bird began to sit some time between January 21 and 25. It was believed to contain young on February 9, and on the 11th the parent was definitely seen to feed the young. On February 19 the bills of both young could be seen above the rim of the nest. On this date observation ceased.

In 1927 a humming bird of the same species built a nest on the nearest available site to the one occupied in 1927, the limb on which that nest was placed having meanwhile fallen. When discovered on January 19 the bird appeared to be incubating. On the morning of January 30 this nest and bird were missing.

On January 11, 1928, a female violet-throated humming bird was discovered building a nest at or very near the site occupied by this species in 1927. She apparently began to sit about January 15.

[14] 1918, Proc. Acad. Nat. Sci., Phila., p. 280.

The date of hatching was not ascertained but on February 3, during the process of feeding, the bills of the young could be seen above the rim of the nest. One of these young left the nest on February 20, the other on February 22. On March 12 a female, presumably the mother of the first brood, was seen on the nest, which had been renovated, apparently laying. On March 14 she began to sit and she was still incubating when last I saw her on March 24.

*Cotinga nattereri.*[15]—On March 24, 1927, I discovered a nest of Natterer's cotinga in the sand-box tree. So far as I am aware it is not only the first recorded nest of the species but of any member of the group of blue cotingas. It was about 90 feet above the ground, halfway between the trunk and the terminal twigs in the angle formed by an orchid growing from the side of a nearly horizontal limb about 5 inches in diameter. It was occupied by a female brooding two young that were covered, apparently, with snowy white down.

On March 31 the young were missing and on April 2 the nest was partly pulled to pieces by the female. During this period no male cotinga was seen.

On February 8, 1928, a female cotinga was seen building a nest in exactly the same place occupied by this species the preceding year. February 16 the female was on the nest, evidently laying, and from this date she was seen sitting on the nest until March 12. On March 13 she was missing and no cotinga was seen until March 20 when a female was observed perched in the top of the sand-box tree for about 30 minutes. She was not seen to visit the deserted nest. Four days later a female was seen in the sand-box tree with a rootlet in her bill and on March 28 a female began to build a nest on the north side of the tree, slightly above and about 50 feet from the abandoned nest.

It seems not improbable that the owner of the first nest, having been robbed of her eggs, had started a new nest. However that may be, I give these facts for the additional proof they afford that tropical birds may return to the same nest site and nest at approximately the same date in successive years. If the nest of 1928 had not been disturbed, the dates given indicate that the young would have hatched shortly, when on March 24, the nest would have contained young of approximately the same age as those discovered in the same nest site the preceding year.

On two occasions a female *Cotinga nattereri* was observed on the sand-box tree in 1926, but, as I have before remarked, the tree was not then under close observation and no nest was discovered though it is by no means unlikely that one existed.

[15] I include certain of my notes on this species for the bearing they have on localization, periodicity and sexual relation in *Zarhynchus*.

On only three occasions during the three seasons I have passed on Barro Colorado have I seen a male *Cotinga nattereri* near the laboratory. None of these was in the sand-box tree. Two perched for a few moments at the top of a dead tree about 100 feet from the sand-box tree. They were alone. The third was at the border of the forest, 120 yards from the sand-box tree. A few minutes after he flew back into the forest a female cotinga left the forest from nearly the same place and flew to the nest in the sand-box tree. This was on February 14, 1928, when my observations indicate that the female was laying. It is not improbable, therefore, that the sexes were associated on this occasion.

*Thraupis cana.*—A pair of blue tanagers nested in the oropendola tree in the season of 1927 and 1928. They selected for their site a large mass of parasitic plants (the lower side of which was occupied by a colony of stingless bees) where it was not possible to watch them closely and I have no notes on the progress of their nesting.

An iguana (*Iguana iguana*), between four and five feet in length, was usually present in the sand-box tree and on occasions two smaller ones were observed. They would lie motionless for hours stretched out on the larger, upper limbs, apparently sunning themselves. Rarely they ate the leaves of the tree. None of the birds that frequented the tree were seen to notice them, nor were the iguanas concerned with the birds.

## SUMMARY OF OBSERVATIONS ON A NESTING COLONY OF OROPENDOLAS (*ZARHYNCHUS WAGLERI*) ON BARRO COLORADO ISLAND, CANAL ZONE

The tree occupied by the oropendolas, when, in 1924, the laboratory was established, having fallen in June of that year, the present site was selected the following year. The new tree, which is believed to have been chosen chiefly because of its proximity to the former home, does not apparently offer the advantages of the fallen one and the colony appears to be decreasing in numbers.

The birds exhibit much regularity in the date at which they begin to nest. In 1926 and 1927 nest building began on January 8, in 1928, on January 2. A humming bird (*Anthracothorax nigricollis*) and a cotinga (*Cotinga nattereri*) that nested in the oropendola tree showed a similar regularity in site and date. While the nesting season coincides roughly with the dry season, the exact time of its inauguration does not appear to be closely dependent on the rainfall. Temperature apparently presents too little variation to be a controlling factor. The return of these birds to the same place year after year illustrates the homing instinct, while the seasonal regularity of their visit is in evident response to those annual prompt-

ings of the reproductive system which are believed to have been the fundamental motivating factors in the origin of bird migration.

Data on a second or supplementary nesting season are not conclusive.

The females outnumber the males about six to one. If this disparity of the sexes is an actual characteristic of the species it may be the cause of the colonial association that permits one male to mate with several females. The males show no marked sexual jealousy. Courtship begins with nest building. A male may woo several females but he apparently has but one mate at a time; the length of this association covering only the period when the ova are ready for fertilization. A similar type of sexual relation appears to exist in the humming bird and cotinga that nest in the oropendola tree.

The males take no part in the selection of the site, gathering of building material, construction of the nest, incubation of the eggs or care of the young. They are, however, in constant attendance on the females either as wooers or accepted mates until the eggs are laid. As watchmen of the colony they play an important part in the protection of the females, particularly in the early stages of nest construction.

Only two other colonies of *Zarhynchus* being known on the island there is no question of colonial territorial rights; but there is often pronounced competition among the females for possession of a nest site.

A new nest is built each year, about one month being required for the completion of the bag and its contained nest. The females then begin to sleep in the nest, leaving the males, who never enter the nest, to return unaccompanied to their roost in the forest.

Two eggs are laid. The period of incubation is approximately 17 days. The young leave the nest about one month after hatching.

The terminal twigs of the nest tree are brittle and in a streng wind sometimes break. Nests that fell from this cause contained both eggs and young but were not found to be infested by parasites. The only ascertained enemies of the oropendolas were other birds. They are parasitized by a cowbird (*Cassidix*), and a flycatcher (*Legatus*), no larger than a phoebe (*Sayornis phoebe*), constantly harries them with the evident purpose of securing possession of one of their nests for its own uses. The building female is at times susceptible to attack by hawks, from which it appears to be the duty of the male to guard her. In response to his alarm call the entire colony dives hastily into the lower forest growth. An owl (*Pulsatrix*) makes an opening in the lower part of the nest bag and the oropendolas appear to be at the mercy of this foe. The inaccessibility of the nest site, and impregnability of the pendant, strongly woven nest bag are, therefore, more apparent than real. Furthermore, the conspicuousness

of their homes offsets the advantages of colonial nesting with its implied absence of marked sexual and territorial jealousy and increased protection through the community interests that make the enemy of one the enemy of all.

*Zarhynchus* can not lay the slightest claim to the possession of a protectively hued plumage. In color, size, and habit, during the most critical period of its annual cycle, it is highly self-advertising. Its safety depends on that constant vigilance which keeps it ever on the alert and on the instant, unquestioned obedience to the alarm note that prompts it to dive headlong into the dense vegetation from which it is never far distant.

POSTSCRIPT

The day that this paper was completed I received word from Mr. James Zetek, resident custodian of Barro Colorado, that the sand-box tree in which the oropendolas nested was blown down by a severe windstorm on August 28, 1928. Evidently, like its predecessor, this tree, as a member of a forest community, had not developed sufficient hold upon the ground to stand alone.

I had hoped that this contribution to our knowledge of the nesting habits of *Zarhynchus* would form the opening chapters of a history that would increase in interest as added data enabled us to view the present in the light of the past. But so far as the sand-box colony is concerned I can now write only finis.

SECOND POSTSCRIPT

On March 8, 1930, what for various reasons we believe to be the laboratory colony of oropendolas was found in a large almendro (*Coumarouna panamensis*) situated about a mile from the laboratory near No. 14 on the Shannon Trail.

On January 8, 1931, 17 oropendolas, including 4 males, were observed in this tree. They had evidently begun to build on January 6 or 7. These dates are so near those records for the laboratory colony (Jan. 8; Jan. 8; Jan. 2; *antea*, p. 352) that they further emphasize the seasonal regularity of the breeding of these birds on Barro Colorado and, at the same time, confirm our belief that the laboratory colony moved to the almendro.

# THE RISE OF APPLIED ENTOMOLOGY IN THE UNITED STATES[1]

By L. O. Howard

At the tenth annual meeting of the Agricultural History Society, held September 13, 1927, my highly esteemed friend, Dr. B. T. Galloway, presented a review of the development of plant pathology in the United States; and his introductory paragraphs apply so well to insect damage that they might well be used for the present paper, simply substituting the words "agricultural entomology" for "plant pathology."

It is true that economic entomology is an older applied science, and hence it is true that for many years the entomologists looked upon the plant pathologists in the somewhat patronizing way that an elder brother looks upon a much younger one. In fact, as the years went by a certain amount of good-natured chaff was heard between the men of these different kinds of work. The entomologist was apt to say, "There is nothing of a practical character in plant pathology except the recommended use of the Bordeaux mixture under all conditions." I recall that I made that remark once to Doctor Galloway and that he countered immediately by saying "There is, after all, nothing to economic entomology but the application of arsenicals for chewing insects and of dilute kerosene emulsion for sucking insects."

All that, however, is quite aside from my present purpose.

I have just returned from a long trip across the country. I have seen at Riverside and Berkeley, at Seattle, and at Minneapolis, at Madison and at Urbana, large classes of earnest young men and women studying applied entomology; and at five of these places I have seen large corps of teachers, admirably equipped, all good research men, engaged in this teaching work. I have seen that the popular estimate of the entomologist has become very high. I have asked some of these teachers whether they felt, on account of their occupation, the faintest indications of an inferiority complex. All replied at once that they were proud of their work, that they were convinced of its great importance, and that they considered themselves among the most useful members of their respective faculties.

[1] Paper read at the twelfth annual meeting of the Agricultural History Society, Washington, D. C., Apr. 29, 1929. Reprinted by permission from Agricultural History, Vol. III, No. 3, July, 1929.

Moreover, I have seen, contrary to the old ideas, that the fear of insects is increasing; that people realize that they are causing increasing damage to humanity in an increasing number of ways.

Last Friday the United States House of Representatives, after a 10-minute discussion, passed a joint resolution appropriating $4,250,000 to be expended in an effort to exterminate the Mediterranean fruit fly in Florida. This morning the Senate, without discussion, passed the same resolution. Two years ago the Congress appropriated the very great sum of $10,000,000 to be spent in an effort to retard the westward march of the European corn borer. Fifty-three years ago, after the Rocky Mountain locust, or western grasshopper, had devastated large portions of four of our Western States, not only causing enormous financial loss, but bringing starvation and disease to very many people, a bill was introduced before Congress to appropriate $25,000 for a commission of entomologists to investigate locusts and to try to find means to prevent future damage of the sort. The Congress, after long consideration, reduced the amount from $25,000 to $18,000, and a bill for the latter amount was passed.

Now what has caused the change between the conditions as I have described them as of the present and the condition that existed only a little more than 50 years ago? That is the story that I am trying to tell elsewhere in some detail, and I will brief its salient points in this paper.

Let us assume that the territory now covered by the United States of America was in a condition of at least temporary stable equilibrium in regard to its animal and plant life at the period when settlement by the white race began. For a great many years the increase in the white population was slow. Agriculture was of small extent and spread out slowly into the forests and plains. There was very slow communication with other countries and none at all with any but those of Europe. There was practically no chance for the accidental importation of insect pests. The crops that were cultivated were in large part of the sorts that were new to the country. Native insects at first did not damage them seriously, and down to the period of the War of the Revolution there were few complaints of insect damage.

After the revolution, however, from time to time the scarce newspapers that paid attention to agriculture would record the unusual abundance of some pest; but on the whole no attention was paid to the subject that would warrant mention in a brief paper like this. The only great crop pests that had come to us from Europe prior to the revolution were the codling moth and the Hessian fly.

Prior to 1800, the only writer on the subject we need mention here was William Dandridge Peck (1763–1822), who was professor of natural history in Harvard College and who wrote in 1795 about

the cankerworm. He followed, in the early years of the nineteenth century, with several papers on various injurious insects.

In 1841, Dr. Thaddeus William Harris, librarian of Harvard College, published a report on "Insects injurious to vegetation in Massachusetts." It was a scholarly work, and it treated of many plant-feeding forms. There was no mention of any critical danger, and the remedies suggested were little more than of the old Scotch gardener type.

A few years later (1853) Townend Glover received an appointment in the Bureau of Agriculture of the United States Patent Office. One of his numerous duties was "to collect information on insects."

The next year, Dr. Asa Fitch of New York was authorized by the New York State Legislature to examine insects, "especially those injurious to vegetation," and thus became practically the first State entomologist. He published a series of reports from that time until 1872. They were full and careful reports, and in them he described the life histories of many important species but brought out nothing striking in regard to methods of control.

Benjamin Dann Walsh, a trenchant writer on entomological subjects, was acting State entomologist of Illinois in the year 1867. He was a man of high culture, broad views, and a prophetic mind. He was especially and harshly critical of many of the remedial measures then in vogue, and was particularly keen in his criticisms of the fake remedies that were then being foisted on the public and as a matter of fact are still being advertised from time to time. Referring to such so-called remedies, one of his phrases sticks in my mind: "Long live King Humbug! He still feeds fools on flapdoodle!" He published but one report, although he had previously been an associate editor of a journal, published in Philadelphia, called "The Practical Entomologist," and later was associate editor, with C. V. Riley, of The American Entomologist, a journal devoted largely to practical matters in entomology.

In 1878 Glover was retired from the position of entomologist to the United States Department of Agriculture, and Charles Valentine Riley was made his successor. Riley served until 1894, with the exception of the years 1879 and 1880, during which period John Henry Comstock (before and afterwards professor of entomology at Cornell University) held the position.

The work done by Riley and Comstock in the Department of Agriculture was of the highest type. Riley had previously served as State entomologist of Missouri from 1869 until 1876 and had published nine reports, admirably illustrated and very sound, which did much to show the importance of careful work. These Missouri reports are full of notable things and from the practical point of

view one of the most striking is the effective work that he did in the investigation of the grapevine Phylloxera and in the subsequent selection of resistant vine stocks from the United States for shipment to Europe for grafting purposes. He thus played an important part in the saving of the wine industry.

During the two years that Comstock served at Washington he accomplished a number of important things. One of them was the preparation of a large volume on cotton insects, but still more important was his study of the scale insects. He worked out the classification and life histories of very many of the injurious scale insects of the United States, an accomplishment that proved to be of the greatest value, since in the ensuing years many scale insects proved to be extremely injurious.

During Riley's final term of office (1881–1894) progress was great. Many important investigations were begun. The entomological service was made a division, and the funds for research were slowly increased by Congress. Aside from the rather elaborate annual reports, many bulletins and circulars as well as a few special reports were published. Seven volumes of an important illustrated periodical bulletin called "Insect Life" were also published and very widely circulated. The achievement of Riley's administration, however, that attracted the widest popular and scientific interest was the brilliantly successful introduction of the Coccinellid, *Vedalia* (*Novius*) *cardinalis* from Australia to destroy the cottony cushion scale in California. This scale was causing the citrus growers of that State the greatest alarm. The very existence of citrus culture in California was threatened. Some orchards actually went down under the ax. But in a very few months after the introduction of the little beetle all fears were gone. So rapid was the multiplication of the introduced insect and so great was its voracity, that the scale insect soon ceased to be feared. This was the first large demonstration of the possible value of the introduction from one country to another of the natural enemies of an introduced insect pest.

In 1876, as indicated in a previous paragraph, the Federal Congress appropriated $18,000 to be spent by a commission of three men to investigate the Rocky Mountain locust. This action was the first national legislation of any importance of this kind. It was largely brought about by hard and intelligent work on the part of Professor Riley. It is interesting to note that while the bill making this appropriation was under discussion in the House, The Nation, considered at the time to be possibly the leading journal representing the best public opinion, published in its issue for March 16 the following satirical note:

> The Republicans in the Senate, not to be beaten at investigations, have passed a bill to investigate insects injurious to vegetation—the locust, the

chinch bug, the army worm, the Hessian fly, and the potato bug. The bill provides for an investigator in chief at a salary of $4,000 a year, the Herculean labors of the head of the Agricultural Bureau preventing that official from giving the necessary time to it. The act, should it pass the House—which seems doubtful—will be a new application of the great principle of division of labor, for in future the Agricultural Commissioner will scatter the seed broadcast over the land, while the national entomologist will follow closely on his trail and exterminate the various bugs that may attack the ripening grain. We only want now another commissioner to harvest the crops, and another to see that they get to deep water, and the husbandman will be entirely relieved from grinding toil.

It was ideas of that sort and public opinion of that kind that Riley and his colleagues had to combat in those days; and the progress made in the face of ignorance and apathy is extraordinary.

When Riley left Missouri his place as entomologist of that State was not filled. Illinois appointed Dr. William LeBaron as successor to Walsh, and he in turn was succeeded by the Rev. Cyrus Thomas, who was followed by Dr. S. A. Forbes.

With the passage of the Hatch Act in 1888 and the starting of State agricultural experiment stations, a very considerable impulse was given to work in entomology; and the creation of positions, enabled by this act, turned the attention of a number of good young men in this direction. It seemed for the first time that there might be a career in economic entomology. As a result also, the teaching of economic entomology received a great impetus. New departments of this kind were established in the agricultural colleges and State universities. The demand for teachers at first was so great as to exceed the supply of trained men, and the early publications of the agricultural colleges and experiment stations were for the most part compilations from the writings of Fitch, Riley, Walsh, LeBaron, Thomas, Packard, and A. J. Cook. A. S. Packard, jr., by the way, had served for two years as State entomologist of Massachusetts, and Prof. A. J. Cook had been lecturing on insects for a number of years at the Michigan State Agricultural College.

Soon after the starting of the experiment stations under the Hatch Act, the Association of Economic Entomologists was formed, and this association has come to be a very powerful factor in the development of applied entomology and in the correlation of the work of the many people engaged.

The closing decade of the last century, however, witnessed four striking events that focused the attention of very many people and of very many countries on the subject of insect damage. The gipsy moth and the brown-tail moth were found in Massachusetts; the cotton boll weevil crossed the Rio Grande from Mexico; the San Jose scale was found in the East, and insects were discovered to carry certain diseases of man and of domestic animals.

The great struggle against the gipsy moth, that has continued down to the present day, has had far-reaching results in several directions. It has hastened the discovery of effective insecticides; it has very largely improved high-power spraying machinery; it has resulted in a very large-scale and long-continued experiment looking toward natural control by the importation into the United States from Europe and Japan of the parasites and other natural enemies of the destructive species.

The advent of the cotton boll weevil has demonstrated in a startling way the possibilities of insect damage. Entering the United States in the vicinity of Brownsville, Tex., it spread year after year until in about 25 years it covered the whole Cotton Belt. It brought about immense money loss; it caused the financial failure of many planters and of many banks; it complicated the labor situation and caused suicides among planters, bankers, and speculators. It called striking attention, however, to the weakness of the 1-crop system, and will prove in the long run to have been beneficial to the Southern States.

The advent of the San Jose scale in the East caused great alarm for a number of years. It was the cause of quarantines against American fruits by most of the countries of the world.

The discovery that insects may carry certain diseases to man and to domestic animals has proved of enormous benefit and has created a new branch of preventive medicine. Work following this discovery has eliminated yellow fever from the United States and from most other parts of the world and has greatly reduced mortality and suffering from malaria and from many tropical diseases. In fact, investigations of this kind have opened up the possible habitation of tropical countries by the white race and the bringing of such countries into the greatly needed food-producing assets of the world.

As time has gone on, since the beginning of the present century, we have seen, partly as the result of these striking events of the preceding 10 years, a rapidly-growing activity in the fight against insects. A very notable event was the passage of the law creating the Federal Horticultural Board administered by the Secretary of Agriculture. By the means of this act the country has been able measurably to protect itself against the importation of new pests from abroad, and the change of this board into the present Plant Quarantine and Control Administration has placed the work of this branch of the public service upon a strong base and will result in a more efficient protection of the country.

In spite of the rapidly-growing activity in the fight against insects, however, there has come strongly to our attention the fact that under present conditions, notwithstanding the increased num-

ber of workers, damage by insects is increasing rather than diminishing; and it has also become apparent that this increase is due almost entirely to our own methods in agriculture.

The population of the country is growing rapidly. Without counting immigration, we are now increasing at the rate of 1,000,000 per year, and that rate itself is increasing. Every year we must feed very many more people than the year before. We must be growing more food constantly. Naturally, all these years we have adopted the quickest, the most economical and the most convenient ways of growing these foods. There have been enormous plantings of single and of allied crops. Often there has been very little rotation. In our haste to feed our increasing millions, we have overlooked the fact that we are feeding increasing billions of insects. By our very methods we are giving certain species of insects the most unprecedented chance to multiply. This will force us in many cases to change our methods—to vary our growing and our cropping systems. We must realize this at once.

It is true that more than half our principal crop pests have been introduced accidentally in the course of commerce. With the passage of the plant quarantine act in 1912, we placed a barrier against this danger; but that it still exists is evident from the Florida experience of the last few weeks. And this Mediterranean fruit fly, the pink bollworm, the Japanese beetle, and the Asiatic bettle, while still more or less local, will probably spread and will utilize to the full the fairly riotous living spread out on all sides. So that, after all, we not only welcome the hundreds of young men who are joining the ranks of the economic entomologists, but we beg for the assistance and cooperation of the farm organizations and the farm leaders and especially the agronomists and the agricultural engineers, and also of the chemists, the physicists, and the plant physiologists. The trained entomologist can follow the life history of a given species. He can study it in all its aspects. He can work out its general ecology. He can find its weak point if it has any. He can find the reasons why it is increasing and spreading. Often he can point out how the greatest damage can be avoided by different farming methods. It is then the agronomist who must advise. The farm planners, the farm organizations, the farm leaders must then take hold.

This is shown very well, I think, in the case of the European corn borer. The great danger from this pest would be nonexistent if it were not for the corn-growing system in a large part of the corn belt. The entomologists have shown that for seven months in the year the borer is helpless at the base of the cornstalks. Is it not obviously the duty of some other than the entomologist to find out the most economical and easiest way of getting rid of the cornstalks at some time during that long rest of seven months?

# MAN AND INSECTS[1]

By L. O. Howard

An article for the Journal of the Maryland Academy of Sciences should necessarily be thoroughly sound scientifically. It should not be written in a sensational way. It should deal with facts and should reason logically from these facts.

I am inclined to think that the best way of stating the case I wish to present will be in a series of limited and definitely stated paragraphs.

1. The insect type is very many millions of years older than the vertebrate type, of which the human species is the latest development.

2. The insect type has, therefore, been tried out very thoroughly under world conditions, while the human species is comparatively in its merest infancy.

3. Many forms of life have been tried, have been found wanting, and have disappeared in the course of the ages, but the insect type has persisted in spite of all cataclysms.

4. The human type may be one of nature's experiments that will fail. It has not been in existence long enough to have been thoroughly tried out.

5. The human species, in spite of its physical disadvantages, has jumped to the fore with unexampled speed owing principally to the evolution of the quality known as intelligence. Through this intelligence it has either destroyed or controlled or converted to its own use nearly all other forms of life.

6. In its very rapid increase and spread, however, the human species has so disturbed the balance of nature as to favor the increase and spread of disease-bearing miscroorganisms and as to encourage enormously the multiplication and spread of injurious insects. In its efforts to feed its increasing millions, it has fed increasing billions of insects.

7. Prophets of evil tell us that human overpopulation of the world is approaching, and approaching rapidly; that mass starvation is sure to come; that birth control is necessary if greater production of plant food can not be stimulated or if new foods can not be invented.

[1] Reprinted by permission from The Journal of the Maryland Academy of Sciences, Vol. I, No. 2, April, 1930.

8. There is a third way of postponing the coming of the starvation era, and that is by the stopping of all waste.

9. Probably the greatest of these wastes is the tremendous but unnecessary tribute that we pay to insects. In the United States alone, the labor of 1,000,000 men each year is lost through insect damage to crops and to our other vital interests. And this damage is increasing. The problem is very much greater than it was even 20 years ago. In order to get the quickest and most abundant food supplies, we are growing our crops in many instances in exactly the way to favor best the increase of crop pests. The cotton boll weevil, for example, might never have been heard of as a serious crop pest if it had not been brought by accident across the Rio Grande and found itself in a whole great State largely devoted to the growing of its favorite food and growing it in just the way to favor the beetle's multiplication to the extreme. The European corn borer, to take another example, would do little harm if we did not farm our cornlands just as we do.

10. It is necessary that we should understand present conditions—that we should understand that insects are our dangerous rivals for the food supplies of the world, and that they are our important rivals and enemies in many other ways. Then it will come about that many men will turn their attention to insect problems. Many men of sound training will study every aspect of insect life. Competent chemists, physicists, botanists, agricultural engineers, and agronomists will take the findings of the increasing number of entomologists, and upon them will base measures for the relief of humanity. The time can not come too soon. Teachers of biology should at once begin to learn and to teach entomology.

Having thus stated briefly and rather definitely what appears to me to be the situation and the general course that should be pursued, I think that it may be of interest to elaborate some of the points.

In the paragraph numbered 5, we have referred to the physical disadvantages of the human species as compared with insects. From the engineering point of view the limb of a vertebrate, with the skeleton inside, other things being equal, is three times weaker than the insect limb having its skeleton on the outside. This outer skeleton of the insect is composed of chitin, an albuminoid that is attacked neither by alkaline solutions nor by dilute acid. It does not grow brittle with age like the bones of vertebrates. The muscles that are exposed in human beings to the slightest injury and are attached to the inner bones, are, in insects, covered and protected by the chitin, and they function better from their numerous attachments to ridges on the inner side of the covering. The insect skeleton is composed of waste material, while the bony skeleton of man is composed largely of proteins and inorganic materials, chiefly lime

and phosphorus. The starches and other substances that make the skeleton of insects, abound in nature; while the diet of man must be selected carefully to include the substances needed for the growth of bone. The blood of insects penetrates to every part of the body, just as it does with us, but the air that purifies the blood also penetrates to every part of the body instead of being confined to the lungs. When insects are born, there is no long period of helpless infancy; they take care of themselves from the start. There is no feeble old age with insects; when their work is done they die before their faculties or their structure have begun to degenerate. There are no bones to grow brittle with age; chitin seems to grow stronger with age.

Together with the advantages already pointed out comes the tremendous advantage of rapidity of multiplication and rapidity of growth and the consequent rapidity of the accommodation of a species to a changed environment. Insects, for example, have all the way from 1 to 20 generations a year, nature trying slowly to make each generation more fit than its predecessor. Place the number at five per annum, as is the case with the cotton boll weevil. Then, in the 35 years this insect has lived in the territory of the United States, it has had 175 generations. An equal number of generations for the human species would fill more than 3,000 years. The advantage in the slow process of evolution and accommodation to changed conditions is evidently enormous.

As to rapidity of multiplication (which differs very greatly with the different forms of insect life) two rather striking examples may be cited. I have shown that, with the common house fly, a single overwintering female may have, between April 15 and September 10, 5,598,720,000,000 descendants. This seems almost incredible, but, given larval food, it is possible. It is not, however, great as are the figures, as startling as the estimate made by Prof. G. W. Herrick of Cornell, of the ponderable mass of the descendants of a single cabbage aphis in Central New York in less than a year. Although a single aphis weighs little more than a milligram, the ponderable mass of its descendants in less than a year would be more than 822,000,000 tons! In pounds, this would be 1,644,000,000,000. Estimating the human population of the world at 2,000,000,000 and the average weight at the exaggerated figure of 150 pounds, the total human weight would be 300,000,000,000 pounds. In other words, the plant-lice descended from one individual of one species in a single season would weigh more than five times as much as all the people of the world. Of course, in this estimate we must grant the existence of food enough for this mass, which of course is impossible.

I have spent the larger part of my time during the past two years in writing a history of applied entomology, and it is interesting to

note how little attention has been paid in the past to the insect problem, except for occasional great emergencies like swarms of migratory grasshoppers, and at the same time how the problem has been growing. Undoubtedly, wherever a center of human civilization had its beginnings, just as soon as food began to be grown on a sufficient scale to feed many people, certain injurious insects began to increase in number. New opportunities for their increase were being offered to them—their increase was really being encouraged. If we had the records of lost civilizations, no doubt these losses by insects would appear; and it is quite within the bounds of possibility that insects have aided in the destruction of past civilizations—such, for example, as those that existed in Central America. Little attention was paid to insects, however, except when great outbreaks occurred, until within the last 170 years; and then for more than 100 years insects were studied by a few men here and there simply as a part of the animal kingdom. They were brought into collections, and classified and named. Their study, however, was considered a trivial pursuit. Within the past 70 years, however, a new type of entomologist has appeared—the economic entomologist, and there has grown up rapidly an increased appreciation of the importance of the study of insects; and the economic entomologists have been increasing rapidly in number, particularly during the present century. The United States has led in this work, and perhaps still leads in the number of persons engaged in entomological research with its economic applications distinctly in view. But other countries are rapidly coming to the front. Entomological problems have seemed more important in the newer countries. The dominions and colonies of the great British Empire have, therefore, felt a greater need for entomological research than most other parts of the globe, with the exception of the United States, and there has been built up in the British Empire many strong research bodies centered in an Imperial Bureau in London.

But possibly it is not the dramatic outbreaks of a comparatively few spectacularly injurious species that bring about the greatest loss. Take agriculture in Europe, for example, where, on account of the small holdings and close methods of cultivation, these great outbreaks rarely get a start. It has become the custom to estimate a normal crop for a certain piece of land. But it seems to the writer that the so-called normal crop would be greatly enhanced if all unnoticed insect damage were eliminated. There are undoubtedly minute unnoticed insects that are constantly lowering productiveness; there are millions of tiny jaws and beaks gaining nourishment from cultivated plants. There must be some way of destroying these creatures and of thus minimizing this damage.

Moreover, there are bacterial diseases of plants and diseases caused by other microorganisms. Upon such diseases there has been built up a great branch of applied science known in this country as phytopathology.[2] But it is beginning to be realized that possibly the majority of these plant diseases are carried and spread by insects, and therefore the control of insects becomes doubly important.

We have not attempted so far to particularize the broad nature of the harm done by insects to the human species. Not only do they consume from 10 to 20 per cent of everything that we try to grow, but they feed upon practically all the stored foods and upon an infinite number of materials that are of use to us. They also affect seriously the health of man and of all domestic animals; and by the carriage of disease, not only to man but to plants, they intensify greatly the problem as it appeared to us only a few years ago.

There is no doubt in my mind that the human species, with its intelligence, will eventually meet this great problem, and that it will bring insect life under control, but down to the present time the problem has comparatively been ignored. In future, not only must the minds of scientific men turn in this direction, but many more men must be educated in such a way as to enable them to conduct profitable research; and, what is more, we must face the fact that we must study our present ways of doing things and particularly our present ways of growing food, and that we must make radical changes in order to bring about the best results.

Intelligence will win out in the long run; but the human species must turn aside in its race and concentrate a great deal of its "God-given" intelligence on its strongest rival, the insects.

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[2] In Europe, the term *phytopathology* is applied to damage done by insects as well as by parasitic microorganisms and viruses.

# THE USE OF FISH POISONS IN SOUTH AMERICA

By ELLSWORTH P. KILLIP, *United States National Museum*, and ALBERT C. SMITH, *New York Botanical Garden*

[With 5 plates]

The Indians who live along the Amazon River and its numerous tributaries have many ways of capturing fish, one of their staple foods. Some of these are ancient methods, handed down from generation to generation; others have come from recent contacts with civilization. There is still-fishing, the natives fashioning hooks from the thorns of plants and from bones, or when the white man's products have reached them, using manufactured steel hooks. Nets of various kinds are much employed, some 1-man circular affairs that require great dexterity to cast, others rectangular nets drawn through the water by several men. Some times the fish are shot with arrows or are speared. Along the lower Amazon, where the tide reaches up from the Atlantic, enclosures are constructed of palm stems, within which the fish are stranded as the tide ebbs. A most modern method is used in regions lying in close contact with the commerce of the world; dynamite is hurled into quiet pools, the natives then diving after the stunned fish or retrieving them downstream by forming a human barricade at a shallow stretch.

But perhaps the most interesting type of fishing is the old native custom of throwing portions of plants into the water to stupefy the fish, a procedure practiced since earliest times by primitive people throughout the world and often mentioned by early explorers of the Americas. With the spread of civilization, the area of this usage is becoming more and more limited. So great is the destruction of fish, small as well as large, that decrees prohibiting the "poisoning" of streams have been promulgated, and where the administrative authority has been sufficiently strong this method has been abandoned. Therefore, to observe this curious method of fishing with plants, to see the plants actually being cultivated for this purpose, and to make a thorough study of these materials, one must penetrate into the more remote parts of the world.

Ample opportunity was had to carry on such investigations by members of a botanical expedition recentlyl sent by the Smithsonian Institution to northeastern Peru and Amazonian Brazil. Reports on the general botanical work accomplished on the trip have been

published[1] by the writers; in the present paper we propose to deal exclusively with our investigations of fish-poison plants.

The principal object of the expedition was the making of botanical collections in the low-lying forested parts of eastern and northeastern Peru, known as the *montaña*. Little botanical exploration had been done in that region; the small amount that has been carried on has mainly been that of European botanists, as Spruce, Poeppig, Ule, and Tessmann, and their collections have been deposited in European institutions. The party consisted of Mr. William J. Dennis, of the University of Iowa, and the writers, and the general route taken was as follows: Brief stops were made along the Pacific coast of Peru, at Talara and Salaverry, the port of Trujillo, and at Lima. From Lima we ascended the cordillera, and proceeded south along this to Huancayo and Huanta. A three weeks' trip took the party over to the Apurimac River, in the montaña, and back to Huanta. Reaching the Chanchamayo Valley by way of Tarma, we then worked slowly over the Pichis Trail, and down the Pichis, Pachitea, and Ucayali Rivers to Iquitos, a city on the Amazon in the extreme northeastern part of Peru. Here the party separated temporarily, Mr. Dennis ascending the Maranon River as far as the rapids of Manseriche, the writers going up the Huallaga River to Yurimaguas and working from there west to Balsapuerto, at the base of the Andes. The return trip from Iquitos was by way of the Amazon River and the Atlantic, with short stops at the Brazilian towns of Manaos, Para, and Gurupa. This circuitous trip from Lima to Para, covering nearly 6,000 miles, gave us a fine opportunity not only to study fish-poison plants but also to discover how little really was known about them outside of the region in which they were actually used.

This method of fishing does not seem to be employed in western Peru, perhaps because of the enforcement of prohibitory laws, perhaps because of the absence of small lakes or slow-moving streams suited to its use. All we learned at Talara and Trujillo was that Indians in the interior used plant roots for fishing. In Lima there was a surprising lack of information about this means of fishing and about the plants so used. At the University of San Marcos there were a few roots on exhibition labeled *cube* and said to be a fish poison of the interior. Dr. August Weberbauer, the eminent botanist of Lima, told us that along the Perene River the Indians used *Tephrosia toxicaria* in fishing. This is a plant of rather wide distribution in the Tropics of the New World, and its use as a fish poison was well known. We felt, however, that it was not the true *cube* of which we had heard.

[1] Explorations and field-work of the Smithsonian Inst. in 1929, pp. 119–128, 1930; Journ. N. Y. Bot. Gard., vol. 31, pp. 81–93, 1930.

At Huancayo, a city situated in the Mantaro Valley at an elevation of about 11,000 feet, *cube* roots were on sale in many shops. They were brought to Huancayo by natives from the montaña, and no stems with leaves or flowers were present with the roots to permit identification of the plant. We learned that water treated with *cube* was sometimes used as a sheep dip in this region. Another plant used both as an insecticide and as a fish poison in the Mantaro Valley was *tallhue*, *Lupinus mutabilis* Sweet (*L. cruckshanksii* A. Gray), plantings of which were seen near Huancayo. The seeds, poisonous when uncooked, were made edible by boiling, the water then being used in cattle-delousing or in fishing.

At Aina, several days of travel southeast of Huancayo and our first stop in the montaña, we were shown a plant in cultivation called *cube*. It was clearly *Tephrosia toxicaria*, and after much questioning we were told that farther inland there was another much more potent fish poison, *cube de almidón* (starch *cube*). The plant at Aina was known as *mutuy cube*, from its resemblance to the well-known dye plant, *Indigofera suffruticosa*, locally called *mutuy*.

The trail we were following ended at Kimpitiriki, a small mission on the Apurimac River, and here for the first time we found the true *cube* plant. Near the mission lived a half-breed farmer, who cultivated a small amount of *cube* for his own use. The plantation consisted of about 100 plants, placed in irregular rows, with 10 feet or more between plants. Here the plants were slender erect trees, 8 to 12 feet in height, with some of the upper branches scandent. These were said to be 2 or 3 years old, and the roots were used at the end of the fourth year (the roots only in this case, although sometimes the stems also are used).

The region is populated by scattered families of Campos Indians, and at the time some of the men had gone on an expedition up the Apurimac to obtain more *cube* root for a forthcoming fishing party. We could not ascertain whether they were seeking wild *cube* or whether they knew of other plantations upriver.

As our plans called for covering a large area in the brief space of seven months, we were unable to explore further this immediate region. How much farther south this particular plant is cultivated we do not know. From reports we judge that it is found all along the Apurimac River until that stream has attained an elevation of 3,000 feet above sea level. At the higher altitudes in the Department of Apurimac this *cube* gives way to other fish poisons. Reports also indicate that it is unquestionably the same as the plant grown along the lower Apurimac and the Ene, the region from which roots are brought to Huancayo.

Although the plants at Kimpitiriki were neither in flower nor in fruit, they were at once recognized as representing a species of the

tribe Dalbergieae, of the Fabaceae (Pea) family. Subsequent studies established its identity as *Lonchocarpus nicou* (Aubl.) DC.[2]

The Chanchamayo Valley, which was next visited, lies east of Lima and across the Andes. So interesting was the vegetation here that a full month was spent in general collecting at La Merced and the Perene Colony, two important settlements in this valley, though only a single plantation of *Lonchocarpus nicou* was seen here. A family of Indians from the interior had taken over a *chacra*, as the small farms are called, and had set out a few branches of *cube*, brought with them from their earlier home. From these some 50 thriving plants had developed. Of special note is the fact that these plants were growing at about 4,100 feet, a higher altitude than observed elsewhere on the trip.

The common fish poison of this region, however, was *Tephrosia toxicaria;* indeed, along that part of the Perene River the Indians apparently use that plant exclusively. At the colony we obtained our first and only information of the use of Sapindaceae as fish poisons. An Austrian immigrant, who had lived many years among the Cashivi Indians to the northward, told of their using various species of a vine known by them as *verap*, and he showed us three different species growing wild in the thickets near his house. These plants proved to be *Serjania glabrata* Kunth, *Serjania rubicaulis* Benth., and *Serjania rufa* Radlk. Along the Pichis mule trail, which begins at the Perene Colony, crosses a range at 6,000 feet altitude, and terminates at the Pichis River, *Tephrosia toxicaria* alone among fish poisons was found, with the exception of a single plant of *Lonchocarpus nicou* at Santa Rosa, near the end of the trail. Along the Pichis, Pachitea, and Ucayali Rivers both of these and a third plant, *Clibadium strigillosum* Blake, called *guaco*, were seen in cultivation, though in no case were the plantings extensive. Apparently the use of fish poisons is being given up along this main route of travel between Lima and the Amazon, possibly from a more rigid enforcement of the laws, but more probably from an increasing use of dynamite. Usually in this region *Lonchocarpus nicou* was referred to as *coñapi.*

Iquitos, the capital of the Department of Loreto, 2,400 miles from the mouth of the Amazon and yet with an altitude of only about 325 feet, proved to be the center of the cultivation of *Lonchocarpus nicou.* From here westward as far as the rapids of Manseriche and Balsapuerto this appeared to be one of the commonest of cultivated plants; indeed, with the exception of bananas, plantains, and *yuca*, it was probably the most commonly cultivated plant. In this region, and in fact at all points north of the Chanchamayo, the name *cube* was never used. *Barbasco*, the general word for fish-poison plants in

[2] See Killip and Smith, The Identity of the South American Fish Poisons *cube* and *timbó*. Journ. Washington Acad. Sci., vol. 20, pp. 74–81, 1930.

Spanish-speaking countries, was applied to all fish poisons, though *Lonchocarpus nicou* was sometimes spoken of as *barbasco legítimo*. The word *barbasco* is said to be derived from *Verbascum*, a genus of Scrophulariaceous plants used formerly in Spain and other European countries as fish poisons. From this we have also *embarbascar*, to fish with poisonous plants, and *barbascal*, a plantation upon which fish poisons are grown.

The *barbascales* of *Lonchocarpus nicou* vary greatly in size from small clearings of 25 to 100 plants, intended to meet the wants of a single Indian and his family, to large plantings of as many as 10,000 trees, the source of supply for a whole neighborhood. This species grows best in fairly open, well-drained, sandy soil, and is propagated by means of cuttings, a piece of the stem about a foot long being placed horizontally a few inches below the surface. The cuttings grow rapidly, and at the end of the fourth year the plants may be as much as 15 feet high. In general appearance they greatly resemble coffee plants, the individual leaflets, indeed, having much the shape of the leaves of *Coffaea arabica*. There is a central main stem or trunk, which in the young stages of growth is erect. Later, if there is a tree trunk available for support, the upper part of the stem may bend toward it and climb upward to a height of 50 feet or more. This accounts for the varying descriptions of *cube* given during the early part of our trip as a tree and a vine. The roots are usually dug at the end of the second, third, or fourth year. The root system of a single individual is very large; one from a plant 2 years old weighed 3 pounds when fresh and 1½ pounds when dry.

In spite of prohibitions concerning it, *barbasco* is used by both aborigines and Spanish-Peruvians. It was our good fortune to attend a fishing party which took place on one of the streams emptying into the Huallaga. Such an affair is an occasion for gayety and excitement. An arm of the stream or a small lagoon where the current is not swift is chosen and on the appointed morning two or three hundred people assemble. Some come from considerable distance, afoot or by canoe. The canoes are substantial craft made of a single tree trunk capable of carrying several people.

Some participants bring large baskets of *barbasco* roots, others who are less provident come empty-handed to enjoy the fun or to get an undeserved share of fish. Many families make temporary camps along the shore, and everyone is in good humor. The *barbasco* is chopped into small pieces with a machete and several basketfuls are emptied into each canoe. It is then covered with water until the canoe is about a quarter full. The men and boys tread this

mixture with their feet until it becomes grayish white in color. Evidently it has no effect on external abrasions; in fact, it is sometimes taken internally in small amounts as medicine.

When all is ready the canoes are distributed over the proposed area and at a signal each participant empties his mixture into the lagoon with a calabash. The *barbasco* left in the bottom of the canoe can be mixed with more water and a second somewhat weaker solution formed. Gradually the quiet water takes on a milky tinge.

After a few minutes, small fish appear on the surface, struggling in an inebriated manner. These are neglected by the fishers and soon float quietly in death; this careless slaughter of innumerable young fish is the chief objection to the use of poisons. Soon the larger fish are affected; the dying struggles of these cause considerable excitement and rivalry. Canoes are propelled to and fro across the agitated lagoon, each with one or more spearsmen in the bow. The spears, equipped with two or three metal prongs, are jabbed into the fish, which are dextrously flipped into the canoe one after another. Shouts of laughter and encouragement fill the air; both paddlers and spearsmen enter into the competition, and many prizes are stolen from beneath the spear of a friendly rival. Along the shores, children emulate their elders by jabbing the neglected small fry.

After a few tense minutes the lagoon is "cleaned out"; only the very large and wary fish are left, the poison having become too diluted to do further damage. The precise effect of the poison is not known, but it is apparently external. In some way the gills cease to function, and the fish act as though paralyzed. Some observers have noted a dilation of the eyes. A fish which is only partly paralyzed, upon being placed in fresh water, will often recover.

Gradually the assemblage disperses, with the prospect of a few hearty meals in the near future. It is said that fish thus obtained can not be kept as long as those otherwise caught, but they are unharmed for immediate consumption. Usually the catch is too large, and the ensuing waste is another score against this method.

By far the greater part of *Lonchocarpus nicou* seen was in cultivation. Only a few scattered plants which we took to be this species were found truly wild in the forests. This wild plant is called *sacha barbasco* by the natives, and there was a difference of opinion as to its effectiveness as a fish poison. Some stated that it was never used; others that it was sometimes used but was much less powerful than the cultivated plant. Perhaps the wild plants represent a species closely related to *Lonchocarpus nicou*, the true plant not being native in Peru; or perhaps the cultivated plant is a selected strain in which the poison content of the roots is particularly strong.

Curiously not a single plant, cultivated or wild, was found in flower or fruit. That this was not due to our trip having been made out of season is evidenced by the universal testimony of owners of plantations, whose powers of observation are remarkably keen, that the plant "did not have flowers." We can only suggest certain explanations for this condition. Possibly the plant does not flower until after several years of growth when it has become a high-climbing liana. As the trees in actual cultivation are dug at the end of the third or fourth year, the great majority of the plants that we saw or that were seen by natives with whom we came in contact were not old enough to produce flowers. Or possibly during centuries of cultivation it has been found that the poison content is more potent in nonflowering individuals.

Other plants cultivated as fish poisons in the Iquitos region and along the lower Huallaga River are *Tephrosia toxicaria*, here sometimes called *tirano barbasco*, and *Clibadium sylvestre* and *C. heterotrichum*, both known as *guaco* or *huaca*.

Our trip across Brazil was unfortunately a hurried one, and we made no thorough study of fish poisons. Questioning of the natives who live along the banks of the Amazon brought little information about the practice. It was only after painstaking search during stops at Manaos, Para, and Gurupa that we were able to see the plants growing. A few scattered plants of *L. nicou* were found near these settlements. Near Manaos there was a planting of over a thousand shrubs of another species of *Lonchocarpus*, *L. floribundus* Benth., the roots of which were said to be very effective as a fish poison. These plants were in fine flower and fruit. At Gurupa on the lower Amazon, there was a third species, *Lonchocarpus urucu* Killip and Smith, which was considered to be even more powerful than *Lonchocarpus nicou*. Other fish poisons cultivated about Para were *Tephrosia toxicaria*, *Tephrosia emarginata*[8] and *Clibadium sylvestre*. On our entire Amazon trip we learned nothing of the many other plants mentioned by Martius and Radlkofer as being used to obtain fish. Here, as in many other places, this mode of fishing is being abandoned because of prohibitory laws. At Manaos all agreed that the Indians of the upper Rio Negro and the Rio Branco used plants almost exclusively in fishing.

In Amazonian Brazil the prevailing name for fish poisons was *timbó*, modifications of this being used for the different plants, as *timbó legitimo* for *Lonchocarpus nicou*, *timbó urucú* for *L. urucu*, *timbó cururú* for *L. rariflorus*, a common plant though apparently not used as a fish poison, and *timbó de Cayenne* for *Tephrosia toxicaria*.

[8] In our previous paper we referred to this plant as *Cracca nitens* (*Tephrosia nitens*), the name commonly used for this close relative of *T. toxicaria* in the lower Amazon region. True *Tephrosia nitens* apparently is distinct.

On this trip across Peru and Brazil we saw therefore 11 different kinds of plants that were said to be used in fishing. These constitute only a small part of the total number of species reported as South American fish poisons, though we believe that *Lonchocarpus nicou* and perhaps *Tephrosia toxicaria* are among the most commonly used ones, at least in the northern half of the continent. Farther south in Brazil the prevailing fish poisons belong to *Serjania* and *Paullinia*, of the family Sapindaceae.

Several lists of fish poisons have been compiled, the earliest being that of the distinguished Venezuelan botanist Ernst,[4] who included 26 species from South America. Papers by Radlkofer,[5] Greshoff,[6] and Howes [7] brought the total known from South America to about 100.

There has been a revival of interest in this ancient custom due to the discovery that many fish poisons contain substances that may prove of high value in the manufacture of insecticides. So great is the damage wrought upon cattle and crops by the hordes of insect pests that chemists are ever on the lookout for effective weapons to fight them. When experiments are concluded it may be found that the roots used by primitive peoples to obtain an important element of their diet are the means of conserving the food supply of the more highly civilized races.

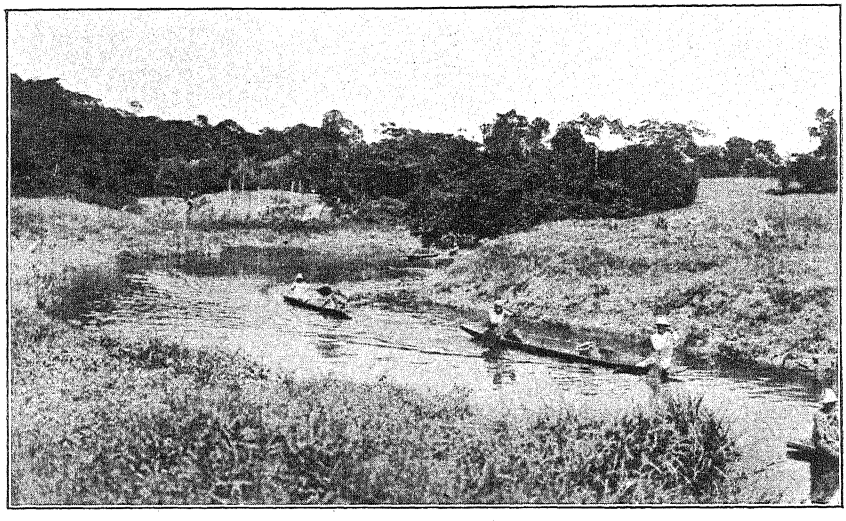
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[4] Memoria botanica sobre el embarbascar ó sea la pesca por media de plantas venenosas, Caracas 1881; reprinted in Anales Acad. Cienc., Habana 18: 135–147, 1881.

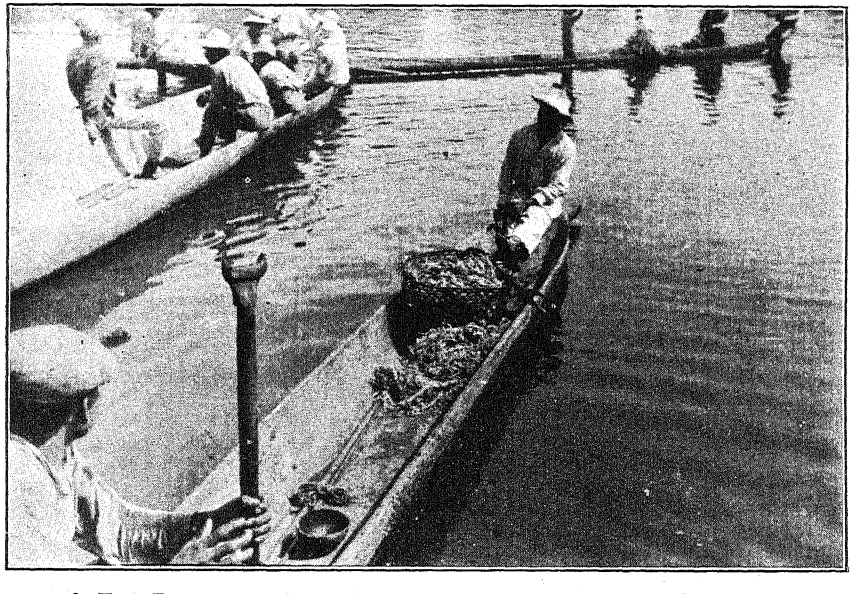
[5] Ueber fischergiftende Pflanzen, in Akad. Wiss. München 16: 379–416, 1886.

[6] Beschrijving der giftige en bedwelmende Planten bij de Vischangst in Bebruik. Medel. 'Slands Plant. Batavia, pt. 1, 1893; pt. 2, 1900; pt. 3, 1913.

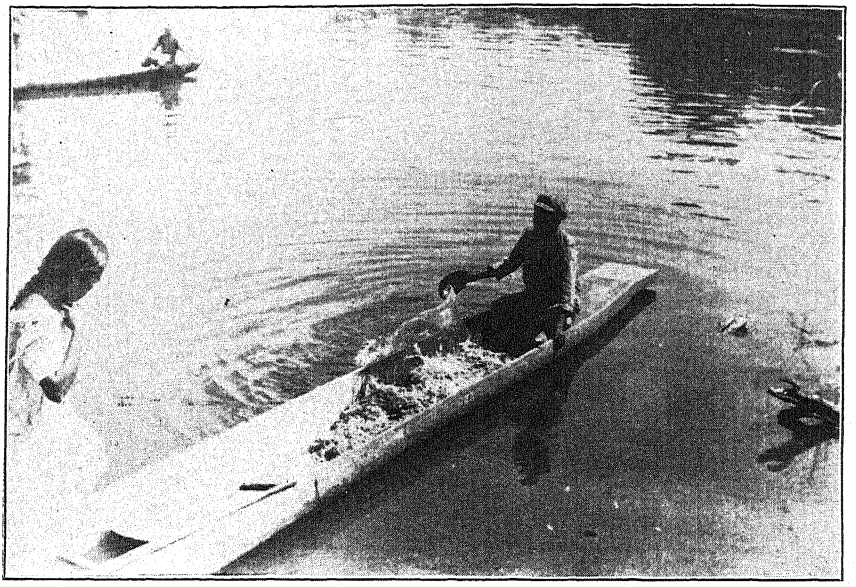
[7] Kew Bull. Misc. Inf. 1930: pp. 129–153, 1930.



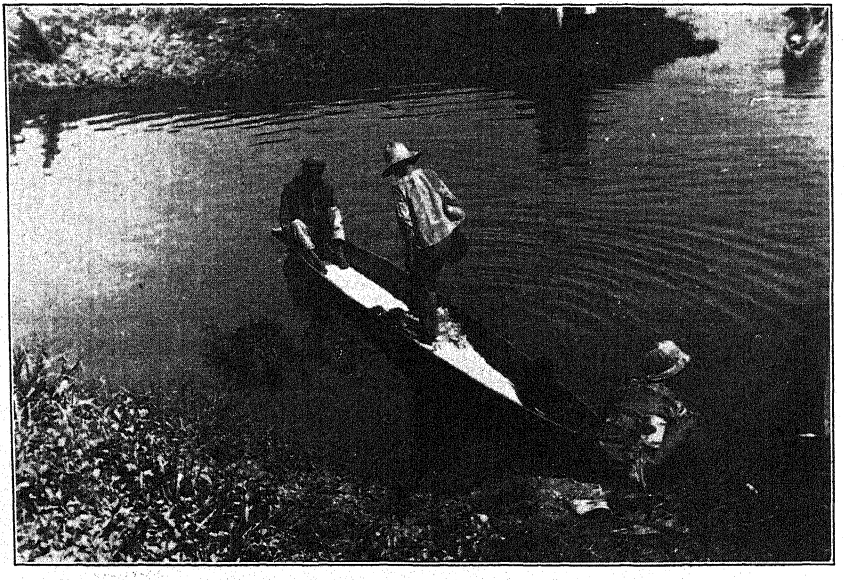
1. FISHERMEN ASSEMBLE WITH THEIR SUPPLIES OF BARBASCO ROOTS



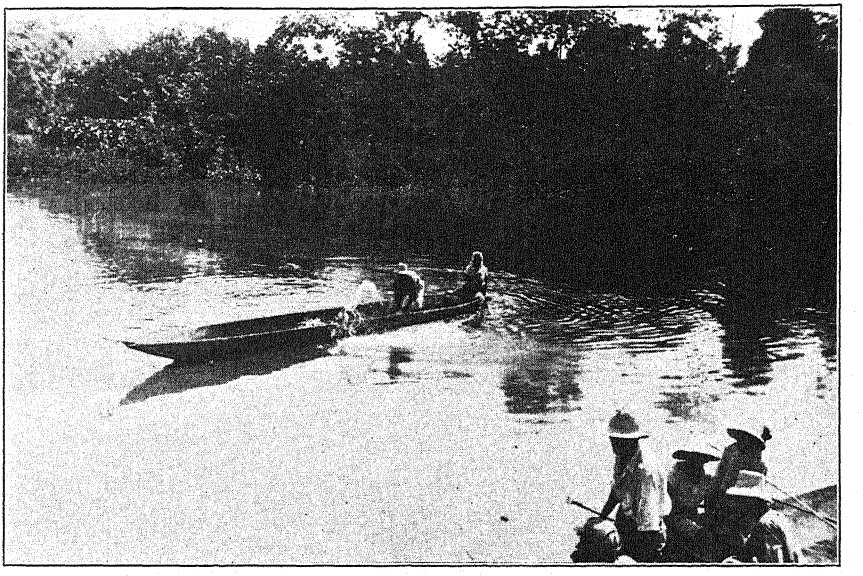
2. THE ROOTS ARE CHOPPED INTO SMALL PIECES WITH MACHETES



1. WATER IS POURED OVER THE ROOTS



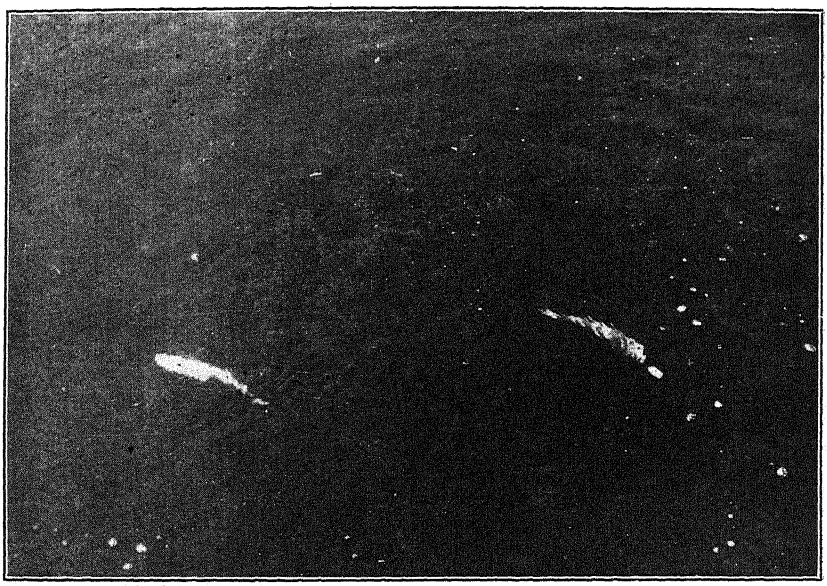
2. THE NATIVES TREAD THIS MIXTURE UNTIL IT HAS BECOME GRAYISH WHITE



1. AT A GIVEN SIGNAL THE "POISONED" WATER IS EMPTIED INTO THE LAGOON



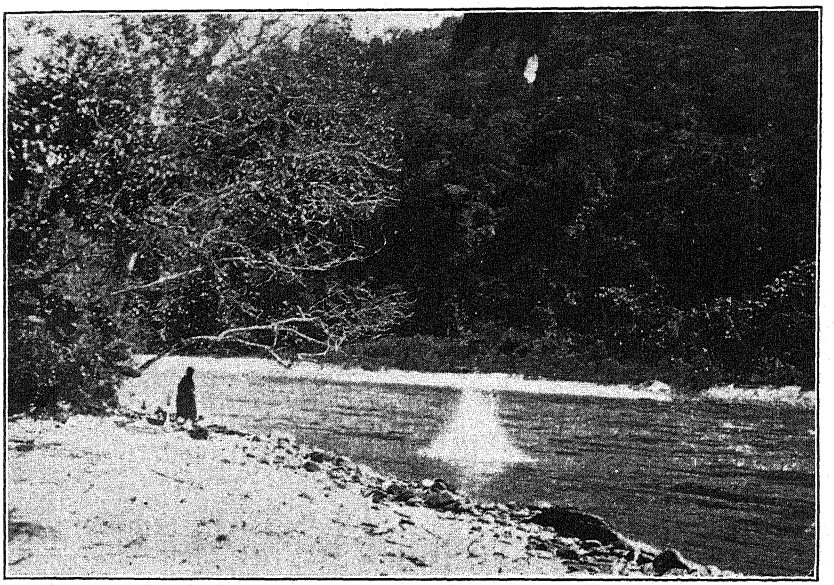
2. THE PARALYZED FISH ARE READILY CAUGHT WITH SPEAR OR NET



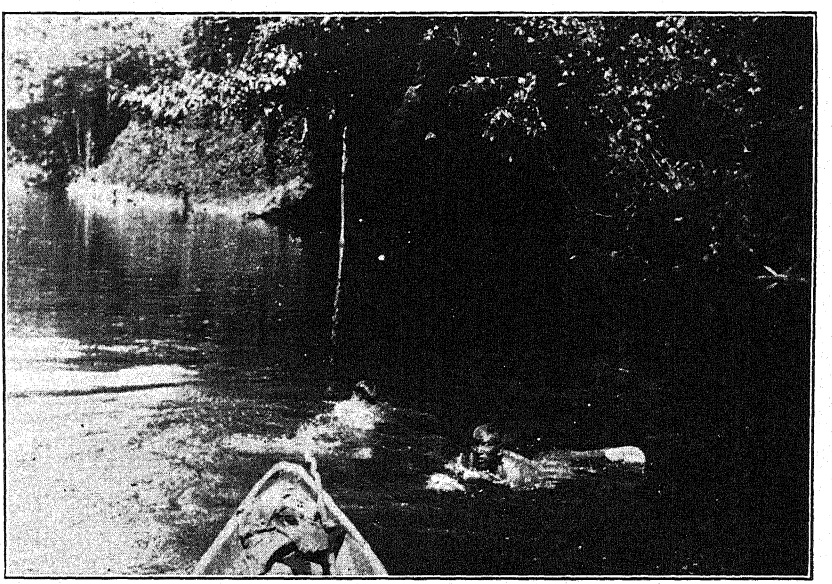
1. QUANTITIES OF FISH FLOAT DOWNSTREAM, STRUGGLING FEEBLY NEAR THE SURFACE OF THE WATER



2. A PLANTATION OF "CUBE" OR "BARBASCO"



1. SOMETIMES DYNAMITE IS USED FOR FISHING



2. THE NATIVES DIVE FOR THE STUNNED FISH AND SOON HAVE A MESS FOR THE COMING MEAL

# A RARE PARASITIC FOOD PLANT OF THE SOUTHWEST

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and

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[With 9 plates]

The rare and interesting plant *Ammobroma sonorae* Torr. is found only in the sand dunes of the southwestern United States and northern Sonora and Lower California, Mexico, where the rainfall averages only about 2 to 5 inches per annum and where there are sometimes periods as long as three years with practically no rain.

Apparently, when plenty of moisture is made available by winter or spring rains the plant grows very rapidly and is able, by stealing from its host and by means of its own roots, to store sufficient moisture in its long, fleshy, succulent stalk to mature and reproduce seed in its chosen home in the sand dunes. In dry seasons this parasite is extremely rare in the sand dunes of Imperial County, Calif., but if the winter months have plenty of rain it is likely to be plentiful there during the months of March, April, May, and June. The larger and better specimens were collected by us in late May and early June following a wet winter season.

Just how this parasitic plant makes its contact with the host root, usually from 2 to 5 feet below the surface, forms a most interesting subject which we are now attempting to solve.

The word Ammobroma is derived from two Greek words, *ammo* (sand), *bromos* (food). The Papago Indians, who have used this plant for food from time immemorial, call it biatatk (*bia*—sand or sand hills—and *tatk*—root).

It is a root parasite and belongs to the family *Lennoaceae* which is usually placed next to the *Ericaceae*, or Heath family. There are only two genera of this family represented in the United States, *Pholisma* and *Ammobroma*, and only one species in each genus, *Pholisma arenium* Nutt., and *Ammobroma sonorae* Torr. In appearance, Pholisma and Ammobroma are quite different, the former

having its flowers in a spike (as a flowering head), while the flower head of the latter is a flat or saucer-shaped disk. The calyx of Pholisma is smooth, whereas that of Ammobroma is quite hairy and the two parasites appear to have different host plants.

Ammobroma is found in the sand dunes between Imperial Valley, Calif., and Yuma, Ariz., and although fairly numerous in spots, appeared not to be widely distributed, even though much apparently suitable territory was explored. Our first examination of this plant was on April 1, 1928, following a wet winter, and thereafter visits to the locality were made at frequent intervals up to July 31, 1929. The plant was found growing in almost pure sand of a pale buffy color, and in the case of the best specimens the roots were found to be in moist sand. Where the sand was dry at the point of contact with the host root the stalks of the parasite were flabby and wilted. They were found more abundant and in better condition in the depressions between the sand dunes or at other points where it was evident that more moisture was available.

The flower heads were flat on the ground, and their similarity in color to the sand caused them to be easily overlooked by a casual observer. There were usually four to eight heads from a single contact on the host root. These heads frequently appear on the surface several feet from the host plant, but they are sometimes closer and occasionally even partially under the branches of the host.

Ammobroma was not reported from California until recently although it was collected in Sonora, Mexico, in 1854 by Col. A. B. Gray and again either in Arizona or in Lower California, Mexico, in 1858 by Carl Schuchard. In May, 1903, T. S. Brandegee reported Ammobroma from California (collected by Alfred Stockton near the Colorado River).

It was reported again in April, 1925, by W. L. Jepson from the Colorado desert in California (Ogilby near Hedges Mine).

Through the interest of Mr. D. S. Hunt (known locally as "Peg-leg"), this rare plant, growing in the sand dunes of Imperial County, Calif., was brought to the attention of Dr. O. F. Cook a few years ago, and in March, 1928, was shown to Mr. Carl S. Scofield. Mr. Scofield collected specimens of young flowering heads and showed them to Dr. Walter T. Swingle at the United States Date Garden, Indio, Calif., in the latter part of March, 1928. Doctor Swingle detailed us to make a thorough study of the plant and in particular to ascertain its host plant.

Before maturity, the heads are like a flat disk with a slight depression in the center, but as they grow older the top becomes more convex, or saucer shaped, and some even approach a funnel shape. When young, the disk appears entire, but may later form folds, or lobes, and in some cases may even split into several parts, radiating

from the center and again dividing as the circumference is approached. This formation seems to take place as the seed vessels develop and may come from pressure of the growing capsules. The edges of the flower head are curled under, and at maturity each ray, in cases where the split occurs, resembles a scape with the persistent flowers on the upper side. The first flowers open near the center, the later ones toward the outside, until the last ones appear near the outer edge. The rays into which the inflorescence splits vary in width according to the size of the disk or the number of the divisions.

The flower heads, or disks, were from 1½ to 5 inches in diameter and about an inch or a little less in thickness. We found one head, however, which measured 8 inches in diameter. The flowers form a scattered circle around the center and in later openings, as stated, approach the outside, thus forming successive irregular circles of flowers. The flower is tubular in shape with a spread of about one-eighth of an inch, and is about three-eighths of an inch in length. The corolla lobes are from six to nine, or occasionally even more, although 6, 7, and 8 seem the most common numbers. The flower is amparo purple and the throat a hortense violet color (Ridgeway's Color Manual), and the margin is white. The filiform sepals are light purple in color with numerous plumose silvery hairs on the upper side which tend to mass or felt at the surface of the flower head, making a soft, velvety surface.

The capsule is shaped like a tiny flat onion, slightly larger than an ordinary pinhead. When mature, it splits horizontally around the equatorial circumference, disclosing a circle of tiny seeds, usually 16 in number. These seeds are shaped like a segment of a tangerine orange and are brown in color, with a rough or pitted surface. As far as could be determined from an examination of our specimens, seed matured from less than half of the flowers. The base, or foundation of the disk, which might be called the receptacle, was light purple and faded to a brown as the plant matured. By soaking this colored substance in water, it appeared to us brown, instead of the expected purple color.

Much difficulty was encountered in digging the plants because fresh sand, which was dry most of the way down, kept sliding back into the hole almost as fast as it could be thrown out, so that in each instance when the work was finally done, we had a funnel-shaped hole, several feet across and usually from 3 to 5 feet in depth. To add to the difficulty, the long fleshy stalks of the best specimens of Ammobroma, usually from 1 to 1½ inches in diameter, were so tender and brittle that they had to be supported by one man while the other did the digging. The stalks were whitish in color, sparsely clothed with scales about an inch long and an eighth of an inch wide, but as the stalks mature the scales take on a tan color. The

scales increase in number and decrease in size from the root attachment to the top of the plant, changing from a brown color underground to a light purple as the head, or disk, is reached. The number of stalks branching from a single contact on the host root varied from one or two to as many as 25, but the usual number was from four to eight.

Rarely did the stalks ascend perpendicularly from the contact point with host root, usually curving horizontally and then upward at various angles. The heads were sometimes close together at the surface, but usually as much as 3 or 4 feet apart. In some instances we found the stalk only part way to the surface and then, instead of a head, it had a sharp point for penetrating the sand. In one instance this sharp point had grown entirely through another Ammobroma stalk at right angles to it.

The young, tender stalks were slightly enlarged soon after leaving the host root, and some of them showed an enlargement just below the surface of the sand. Many of the stalks had thrown out a few roots at the base, or point of contact with the host root, thus indicating an attempt to depart from pure parasitism. In a few cases, as shown by the photographs, there were many Ammobroma roots. When the stalks were in their prime they were very succulent, plump, and very tender and brittle, but as the moisture disappeared and the heads matured, the stalks wilted, decreased in diameter, and became flabby. Apparently the head forms just before it reaches the surface of the sand and then pushes its way up to the surface in a manner similar to the growth of a puffball or toadstool.

When moisture is available under the conditions prevailing in the sand dunes of Imperial County, Calif., this parasite is able to store sufficient moisture and nutriment in its stalk to continue flowering well into the rainless summer months. We collected our largest and best heads on April 26, 1928, at a time when no moisture could be detected in the sand at the point of contact with the host and the roots of the parasite appeared to be dead. The Ammobroma stalks were wilted, indicating that the heads had continued to grow and mature seed from the storage in the stalks.

The disproportion between the small nonsucculent Coldenia host and the heavy, fleshy and succulent parasite is very noticeable, the parasite often being many times the weight of the host. This is possible because the Ammobroma has its own root system, enabling it rapidly to absorb water when available in the sand of the dunes.

The host plants of Ammobroma were not identified by Col. A. B. Gray, who discovered it near Adair Bay, Sonora, Mexico, on May 17, 1854, nor by Carl Schuchard, who in May, 1858, between Pilot Knob and Cook's Well, collected the specimens which were studied so carefully by Count Solms-Laubach.

In 1890, Dr. Edward Palmer collected Ammobroma near Lerdo, Sonora, Mexico, not far from the Arizona boundary, and reported it parasitic on *Franseria dumosa* (Compositae) Gray and *Dalea* (or *Parosela*) *emoryi* (Leguminoseae) Gray. The account of the collecting of the plant by Doctor Palmer is found in the Contributions from the United States National Herbarium, No. 1, June 30, 1890., p. 27:

*Ammobroma sonorae*, Torr. This was first discovered in 1854 by Col. A. B. Gray, in charge of a railroad exploring party, at the head of the Gulf of California. At this time a short notice of the discovery was published by Col. A. B. Gray in Memoirs of the American Academy of Science, but it was not until 1867 that a description of the genus was published by Dr. John Torrey in the Annals of Lyc. Nat. Hist. N. Y. Vol. VIII, p. 51, together with a good figure. So far as we can learn the plant was not collected again until Schuchard got it in Arizona. And now Doctor Palmer collected it in large quantities at Lerdo, Mexico. Until the present season its host plant has been unknown but Doctor Palmer has carefully examined into this, and collected two common plants of this arid region upon which it grows. These are *Franseria dumosa* and *Dalea emoryi*. Doctor Palmer wrote that the plant grows in deep sand, the deeper the sand the larger and juicier the plants. The Cocopa Indians gather them for food, which they relish under all circumstances. They eat it raw, boiled, or roasted. The plant is full of moisture, and whites and Indians alike resort to it in traveling, as a valuable substitute for water. It has a pleasant taste, much resembling the sweet potato. The stems are 2½ feet long and 1 to 4 inches in diameter, but almost buried, only the peculiar white tops appearing above the sand. The Cocopa Indians call it "Oyutch." Colonel Gray gave much the same report of this plant. He says the Papago Indians dry the stems and grind them with the mesquite beans, forming what they call "pinole."

In this same publication, under the heading "Head of the Gulf of California," also on page 27, appears the following:

Three days were spent at Lerdo, Mexico. This is 60 miles south-southwest from Yuma, latitude 31° 46′ 10″, and longitude 114° 43′ 30″.

The most interesting plant found here was Ammobroma, which for the first time has been collected in good quantity.

Since Doctor Palmer's time, no further information has been forthcoming as to the hosts of this parasitic plant, which in the meantime had been reported from Ogilby, Calif., near Hedges Mine, by W. L. Jepson in his book "A Manual of the Flowering Plants of California," page 735, published April 14, 1925.

In the sand dunes east of Holtville in Imperial County, Calif., we found Ammobroma parasitic on *Coldenia plicata*,[1] (Torr.) Cov. and *Coldenia palmeri* Torr. (Boraginaceae) and more rarely on *Eriogonum deserticolum* Wats. (Polygonaceae). We did not see any

[1] An unfortunate confusion has occurred in the names of these two common species of Coldenia. What is commonly called *Coldenia palmeri* Wats. is, according to Ivan M. Johnston (Proc. California Acad. Sci., vol. 4, no. 12, 1143 N. 30, May 31, 1924) not that species but *Coldenia plicata*, (Torr.) Cov., while the true *Coldenia palmeri* Torr. is the species commonly called *Coldenia brevicalyx* Wats. The names are used here in their original sense as determined by Johnston and not in their current application.

Franseria species growing where the Ammobroma was found but we did find a considerable number of *Dalea* (*Parosela*) *emoryi*, none, however, showing it as host to Ammobroma.

In number of plants harboring the root parasite, *Coldenia palmeri* easily led with about 80 per cent of those found. *Coldenia plicata* came next with about 19 per cent, and *Eriogonum deserticolum* supported the parasite in only three instances of the many examined by us. *Coldenia palmeri* was more numerous than *Coldenia plicata* but not in as great a percentage as the relative infestation would indicate.

The two species of Coldenia mentioned herein are quite common in the arid and sandy portions of the Southwestern United States. Under favorable growing conditions, *Coldenia palmeri* Torr. often appears semispherical, sometimes spreading as much as 2½ feet and reaching a height of 1 foot. In dry seasons it presents a very ragged appearance and makes little, if any, growth, depending upon the amount of moisture available. Its roots are very dark in color and extend comparatively long distances into the sandy soil. When the sand of the dunes of Imperial County contained moisture, we noticed frequent enlargements of the Coldenia roots, indicating a tendency to store moisture when available. It shows much better growth where richer soil is available than that to be found in the sand dunes, but apparently Ammobroma prefers almost pure sand.

*Eriogonum deserticolum* Wats. was quite numerous but seemingly not a suitable host. One contact found on Eriogonum was notable in that 25 Ammobroma stalks were growing from a single contact on one root of the host, the largest number found from one plant. However, the stalks were small and wilted and the heads were also small and not well developed. The depth was less than the average, being only a little over 2 feet, while the average for Ammobroma on Coldenia was between 2½ to 4 feet, one extreme depth being 5 feet. This particular case was impressed upon us by the labor entailed in digging it out in the hot desert sunshine with the temperature at about 105°. A careful search failed to reveal any other plants utilized as host, although representatives of other genera were fairly abundant in the immediate locality, among which may be mentioned: *Covillea glutinosa* Rydb., *Ephedra trifurca* Torr., *Abronia villosa* Wats., Var. *aurita* Jepson, *Mentzellia multiflora* Gray, *Stillingia annua* Muell., *Palafoxia linearis* Lag., *Parosela emoryi* Gray, *Petalonyx thurberi* Gray, *Oenothera trichocalyx* Nutt., *Oenothera scapoidea* T. &. G., and *Dicoria canescens* T. & G.

The Papago and other Indians of the southwestern United States regard this plant very highly as food. Where Ammobroma was found, we noted many pieces of broken Indian pottery, some of it worn very thin by blown sand. Ammobroma was discovered by Col.

A. B. Gray near Adair Bay, or Pinacate Mountain, in the State of Sonora, Mexico, in May, 1854. On this occasion he had with him a Papago Indian chief, who gathered some of this plant and roasted it on the coals of his camp fire. In describing its food value, Colonel Gray says:

> We encamped for the night in the sand hills, and the chief, instead of supping with us as usual, made a fire and roasted his roots or plants on the hot coals (which took about 20 minutes), and commenced eating them. None of the party seemed inclined to taste, but out of curiosity I moved over to the chief's fire, and he handed me one. At first I ate but little and slowly, but in a few minutes so luscious was it that I forgot my own mess and ate heartily of it; next morning each of the party "followed suit," and afterwards there was scarcely enough gathered to satisfy us. The taste, though peculiar, was not unlike the sweet potato, but more delicate.

We liked it better raw than cooked; however, we did not try it roasted on coals as described by Colonel Gray. We found it quite palatable and apparently nutritious. Gray, Palmer, and Lumholtz agree that when roasted on the coals Indian fashion it resembles the sweet potato in taste.

Mr. Carl Lumholtz, who many years later found this same plant at about the same locality, says of it:

> I sampled one of them and found it to be a succulent and excellent food. It is more tender than a radish, as well as much more juicy, and the whole root can be eaten. It has a sweetish and agreeable flavor all its own. The Indians usually toast these plants on the coals, when they resemble sweet potatoes in taste, but I prefer to eat them raw. They are an especially delicious relish to a thirsty man, and they also quickly appease hunger; in fact, of all the many kinds of edible roots that I have tried in their uncooked state, used among natives in different parts of the earth, I know of none which can compare with this one in refreshing and palatable qualities.

On the occasion of Colonel Gray's discovery of this plant, May 17, 1854, he says:

> No rain had fallen there for six months, it being the dry season.

Mr. Lumholtz visited this same locality in March, 1910, and he says:

> I had heard much of this plant for even the Mexicans relish the camote of the medanos, as they call it, but the past rainless winter had held out little hope that my desire to see it would be realized.

From this it would appear that both Gray and Lumholtz found considerable numbers of this plant following very dry seasons. Mr. Lumholtz further indicates that the plant in the Pinacate region is available to the Indians as food through the whole year for in speaking of the "Sand-dune Papago Indians" he says:

> They found good edible plant food in the dunes, especially Ammobroma sonorae, the wonderful camotes which the Indians knew how to gather all the year round, though after May that part of the plant which is above ground withers away.

The experience of the authors, resulting from frequent examinations of this plant from April 1, 1928, to July 31, 1929, as it grows in the sand dunes of Imperial County, Calif., indicates that the Ammobroma of that locality dries up during the dry seasons; in fact, but two single specimens were found in the spring of 1929 and both of these were attached to *Eriogonum deserticolum* Wats., a much larger and more drought-resistant shrub than either of the Coldenias, which to Ammobroma appear preferable as host plants.

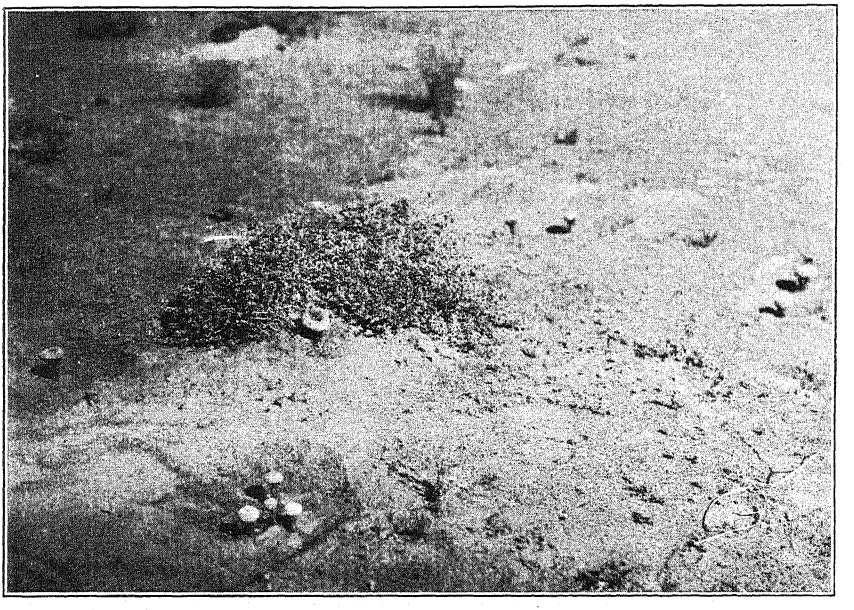
During the dry season (March to June, 1929) we traced many dry stalks of the Ammobroma of the previous season down through the sand to the contact with the root of the host plant and in only two cases did we find any life in the Ammobroma and then only a very little within 1 or 2 inches of the point of contact. However, the difference in our experience and that of Gray and Lumholtz may be due to the fact that the Ammobroma of the Pinacate region of Sonora has a different host plant which may be better able to support Ammobroma through the dry seasons, or there may be more moisture in the sand where they found it.

During the 1928–29 season the most common host plants for the Ammobroma of the Imperial County, Calif., sand dunes, the two species of Coldenia herein mentioned, made little if any growth; in fact, the tops of most of them appeared to be practically dead.

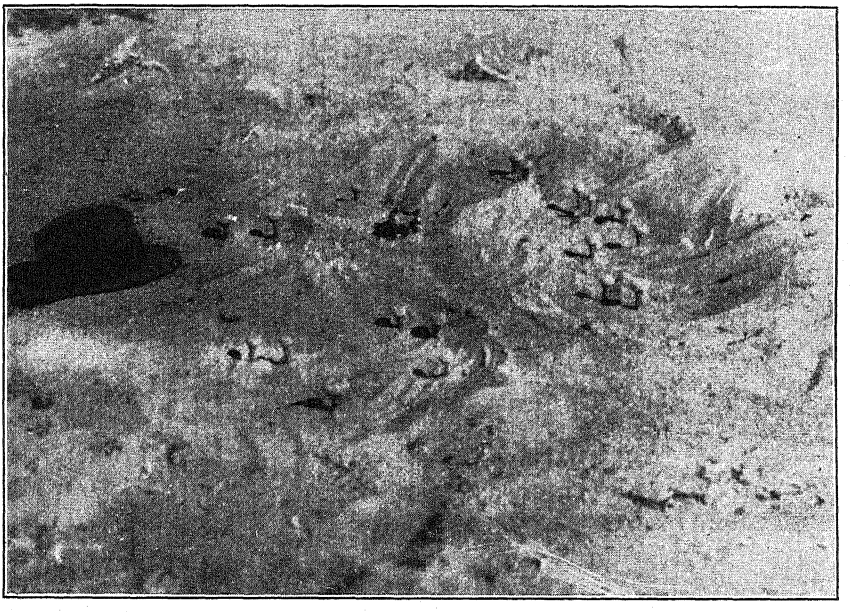
We have procured seed of the Ammobroma and scattered it near the Coldenia of the sand dunes in Riverside County (Coachella Valley), but so far no germinations have been noted.

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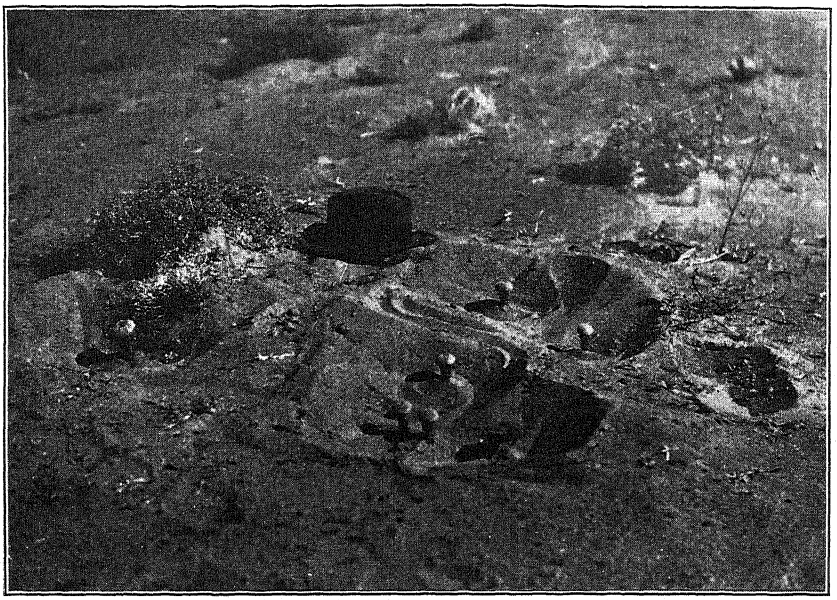
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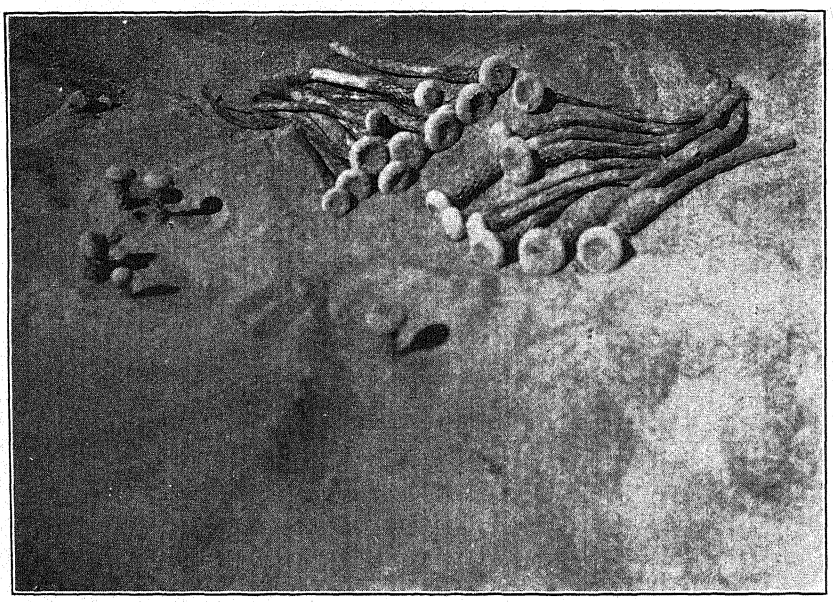
1. ELEVEN STALKS OF "AMMOBROMA" FROM A SINGLE CONTACT ON ROOT OF THE COLDENIA PALMERI; THE LATTER IS SHOWN IN CENTER OF PICTURE. APRIL 1, 1928



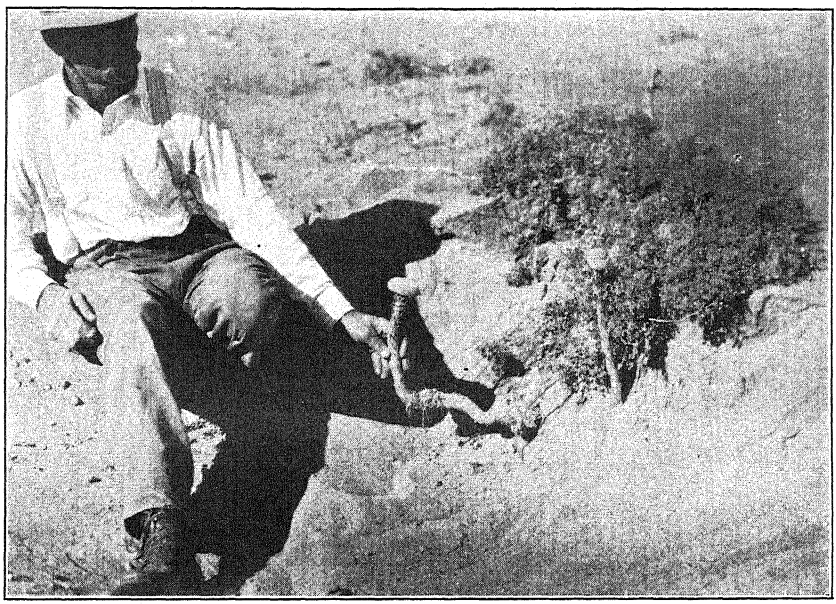
2. SHOWING 19 STALKS OF "AMMOBROMA" FROM SINGLE CONTACT ON ROOT OF COLDENIA PALMERI. APRIL 1, 1928

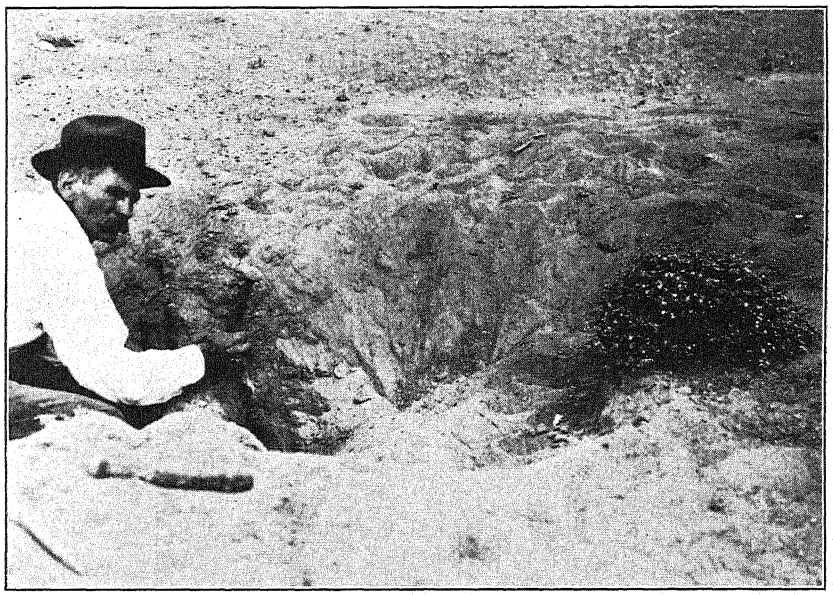


1. "AMMOBROMA" ON COLDENIA PLICATA, WHICH MAY BE SEEN JUST TO THE LEFT OF THE HAT. APRIL 1, 1928

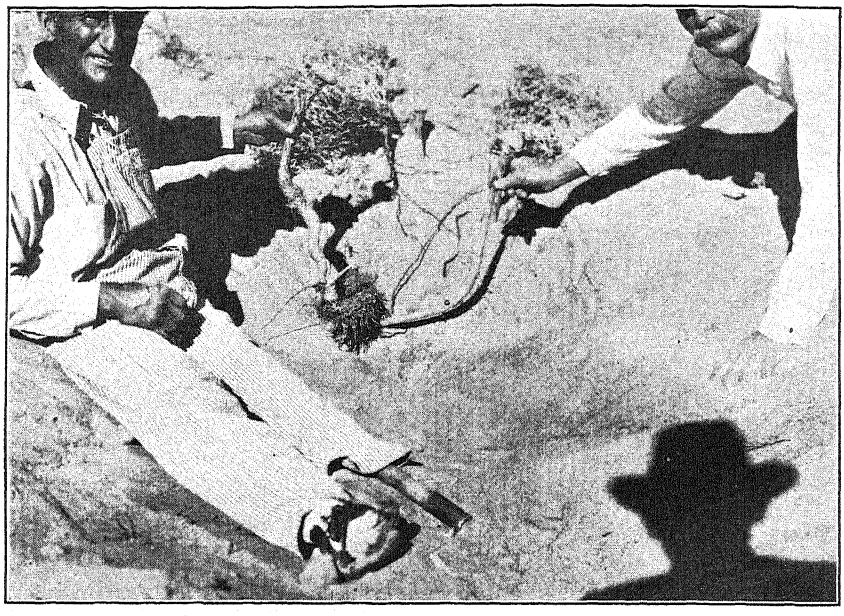


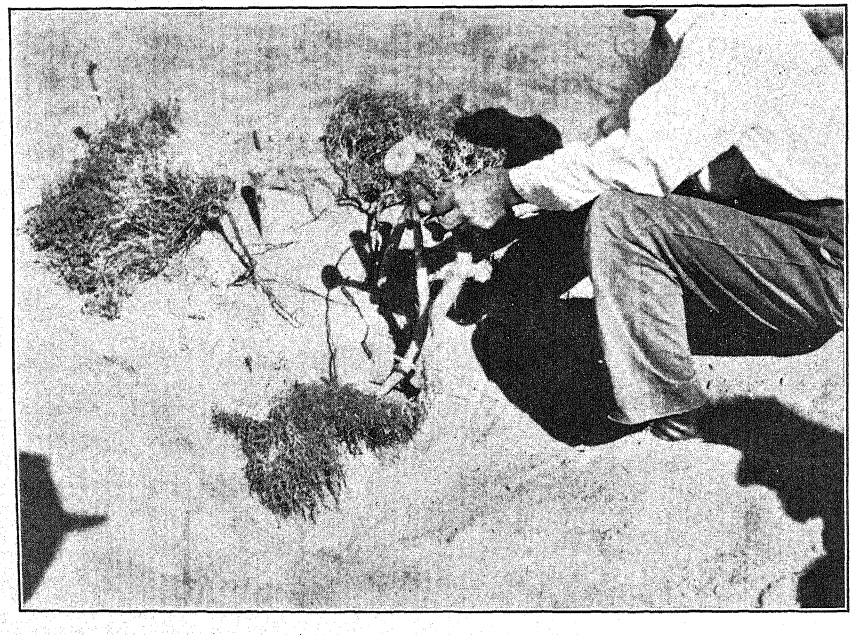
2. SAMPLES OF "AMMOBROMA" AS PULLED FROM THE GROUND WITHOUT DIGGING AWAY THE SAND. APRIL 15, 1928





SHOWING BOTH HOST AND PARASITE. APRIL 1, 1928

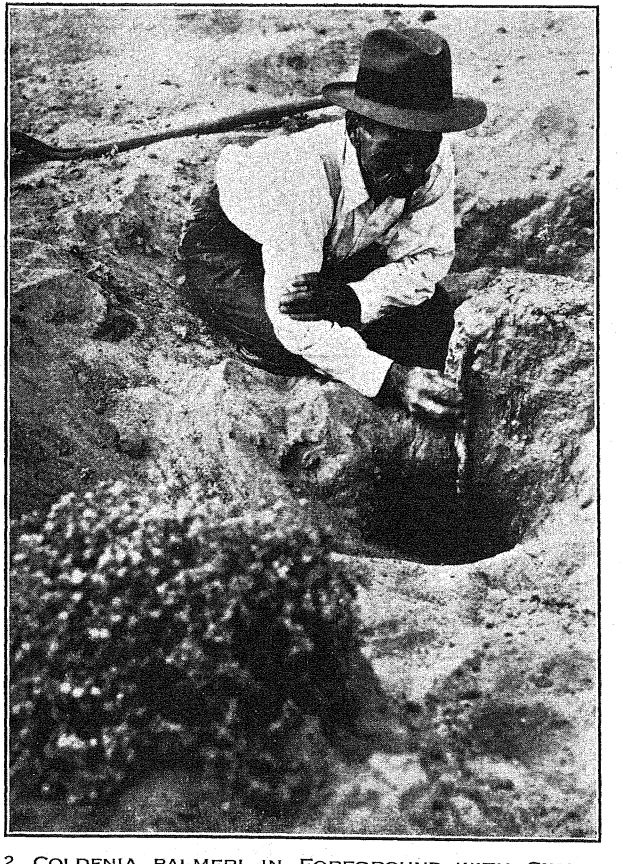




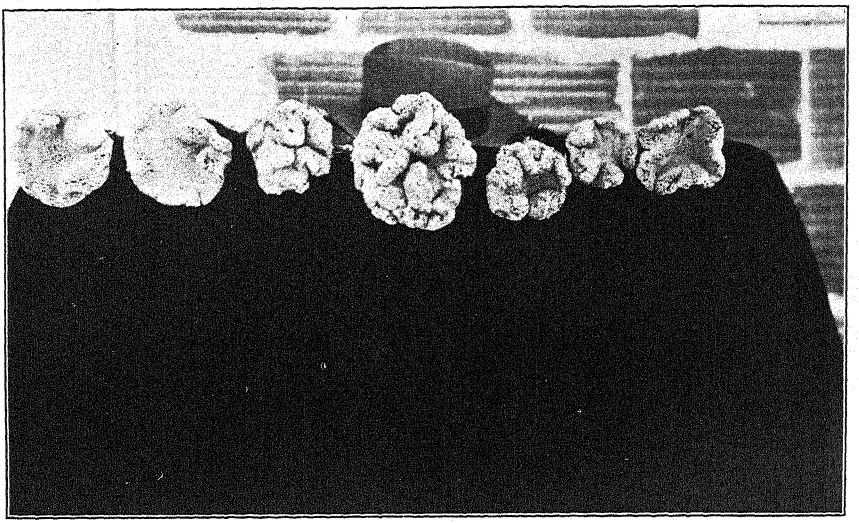
SHOWING "AMMOBROMA" ROOTS AT POINT OF CONTACT ON ROOT OF COLDENIA PALMERI. APRIL 15, 1928



1. SHOWING "AMMOBROMA" ROOTS AT POINT OF CONTACT ON ROOT OF COLDENIA PALMERI. D. S. HUNT IN BACKGROUND. APRIL 15, 1928



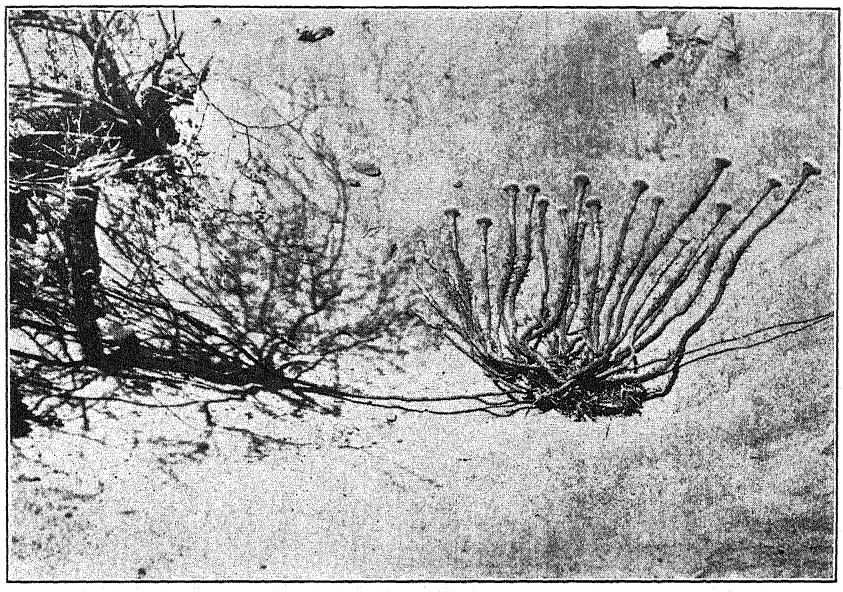
2. COLDENIA PALMERI IN FOREGROUND WITH SINGLE STALK OF "AMMOBROMA" ATTACHED TO ITS ROOT. APRIL 1, 1928

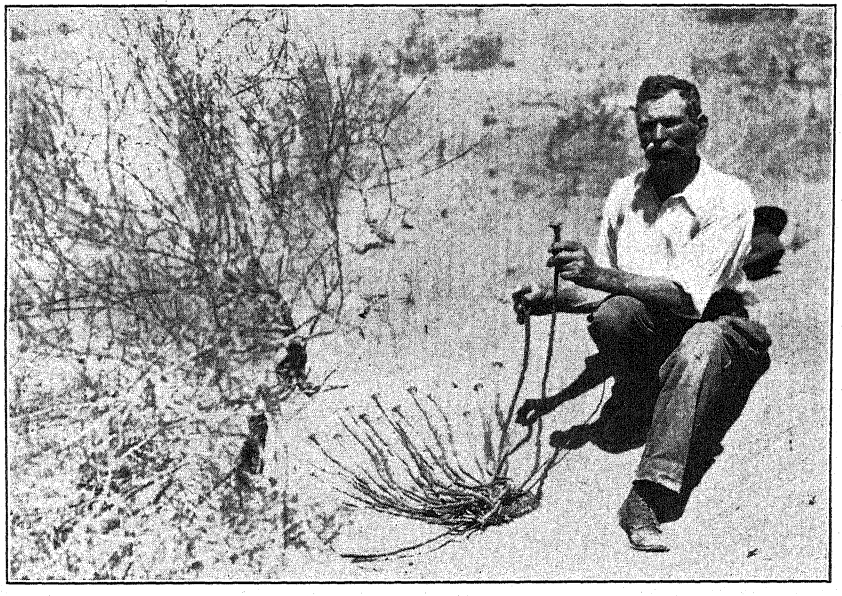




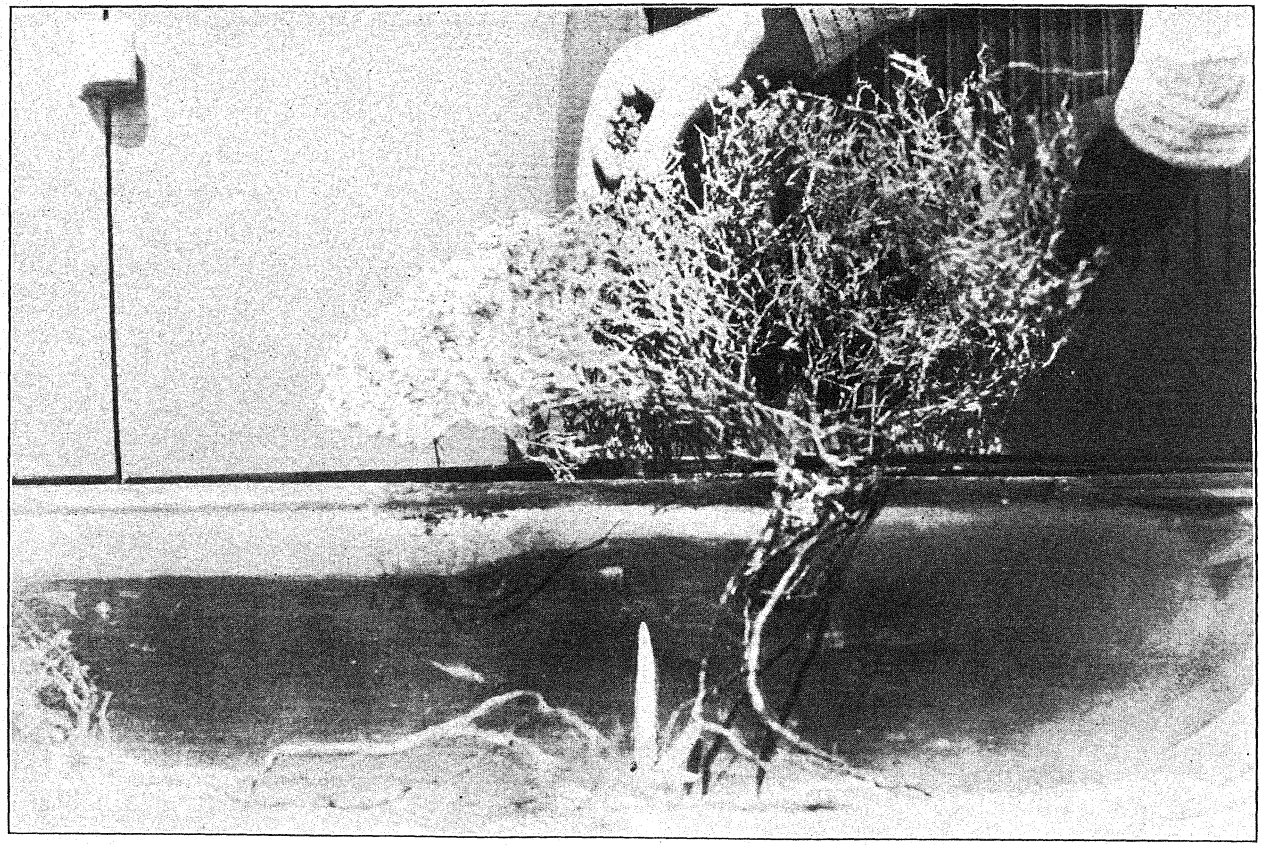
FORMATION OF FOLDS OR LOBES AND SPLITS AS HEADS OF "AMMOBROMA" MATURE

The large head is 8 inches in diameter. April 26, 1928.

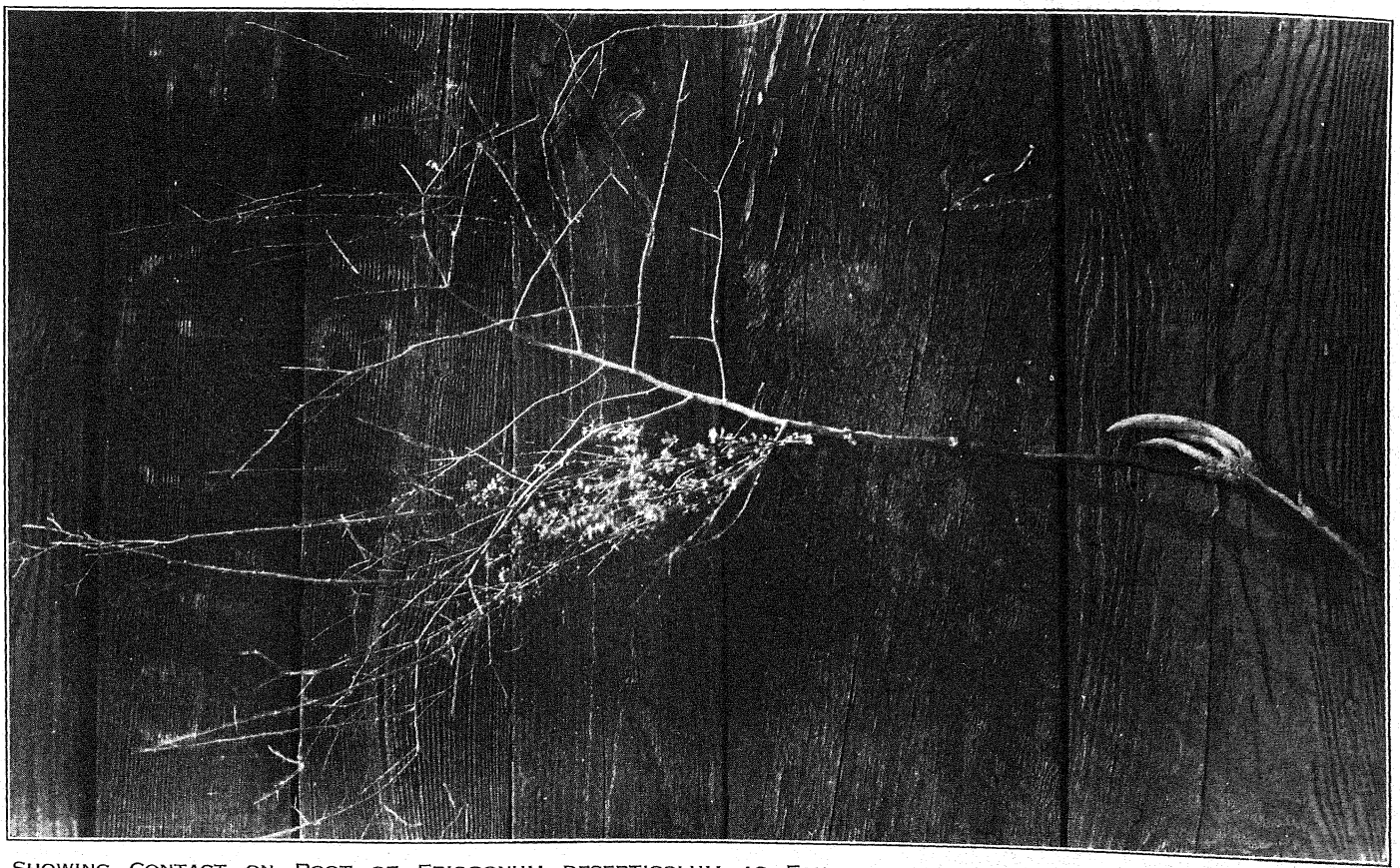




SHOWING CONTACT OF "AMMOBROMA" ON ERIOGONUM DESERTICOLUM.
APRIL 1, 1928



SHOWING CONTACT ON ROOT OF ERIOGONUM DESERTICOLUM AS FOUND BY THE AUTHORS IN THE LATE SUMMER OF 1928



SHOWING CONTACT ON ROOT OF ERIOGONUM DESERTICOLUM AS FOUND BY R. H. PEEBLES WITH THE AUTHORS ON MARCH 12, 1929

# THE MECHANISM OF ORGANIC EVOLUTION [1]

By Charles B. Davenport
*Department of Genetics, Carnegie Institution of Washington*

[With 1 plate]

As we look over the world to-day we see, as the ancients did, the marvelous phenomenon of a world populated not only by humans but also by many hundred thousand so-called species of animals and plants existing in uncountable individuals whose numbers can no more be expressed by the ordinary system of numbering than astronomical distances can be readily expressed in miles. A cubic millimeter of the blood of a leucaemic mouse may contain over a million white corpuscles, and there may well be 1,000 such cubic millimeters of blood in a mouse. This gives us a billion white corpuscles in one mouse not to consider the other cells of the mouse's body. These white corpuscles are essentially organisms, with powers of food gathering, assimilation, excretion, locomotion, sensation, etc. And this is but one mouse. Even if we assume so few as 2½ house mice to a human being on the earth (and mice are ubiquitous), and that each has only 10 million leucocytes, we shall have 50 million billion white blood corpuscles in house mice alone.

I have sometimes speculated on the number of organisms visible to the low power of the microscope that are in our inner harbor [2] at the end of August, when it has a creamy, souplike consistency. Assuming one per cubic millimeter, which is certainly far too small, there would be a quadrillion individuals in this space, which would occupy only a square millimeter in the one-millionth map of the world, which has over half a billion square millimeters.

Pardon me for wearying you with figures. I have wanted to put you in a position to grant my first point that the number of individual organisms on the globe is essentially infinite, though the number of kinds that naturalists have been able to count and describe in the past 150 years is still finite.

Next, I would call to your attention that most of these individuals have a short life and are quickly replaced by others, even if we leave

[1] Presented before the two hundred thirty-third meeting of the Washington Academy of Sciences, as one of the series of papers on Origin and Evolution. Reprinted by permission from the Journal of The Washington Academy of Sciences, vol. 20, No. 14, Aug. 19, 1930.

[2] Cold Spring Harbor, Long Island Sound.

out of account the unicellular organisms which retain their individuality only for the few hours or minutes necessary to reorganize and divide again. Even if we assume that the average length of life of an individual is a year—and it is probably not over a day—then we have to consider the remarkable phenomenon of an annual wiping off of the slate, as it were, of this infinitude of individuals each year and their re-formation the next year. This is possible owing to the immense reproductive capacity of certain species. Thus one oyster may lay 50,000,000 eggs during a few days in the summer and one sea urchin 20,000,000 eggs. These are samples, merely, of reproductive capacity of individuals. Perhaps now we have gained some conception of the number of individuals that have been produced each year on the earth, during we do not know how many millions of years.

If now you are willing to admit that the problem of organic evolution is that of the evolution of an organic mass consisting of an infinitude of individuals reproduced during an infinitude of generations, that may serve as a starting point to our inquiry as to the mechanism of organic evolution.

Now, each individual has a certain recognizable form and acquires it through a certain course of development, be it more or less complex. The center of control of this form is largely, if not chiefly, in the chromosomes of the organic cells—in its genes, to be more precise. In fact the soma of organisms, what we see, is just an index of the form producing and maintaining factors of the genes—always, of course, recognizing that the end result is a sort of reaction between gene and environment. Now if the world of organisms is composed of an infinitude of kinds it is because the germ plasm is of an infinitude of kinds. The course of organic evolution has been and is what it is because the germ plasm has undergone and is undergoing the changes that it has undergone and is undergoing. This change of the germ plasm is called mutation. Mutation is one of the great factors in organic evolution.

Now what do we know about mutation? First, we know that it is widespread. This knowledge has first become precise as organisms have been studied in successive generations, under controlled conditions. Such mutations have long been known among domesticated organisms like potatoes, poultry, guinea pigs, and dogs. Mutations have been so long known among domesticated organisms that it was natural for Darwin to discuss "Variation under Domestication" and for him and others to consider what quality of domestication it is that induces mutation. During the past 25 years in several species of animals taken from the wild, many generations have been followed. And in consequence we now know that mutation has no necessary relations to domestication; but only that

domestication enables us to see and perhaps preserve such mutations. Rather, I should say, the product of such mutation, for the mutation has occurred in the germ plasm before it has become visible in the soma of the organism that develops under the control of the mutated germ plasm.

Let us now consider some of the facts of mutation that experimental study has revealed.

First, mutation is probably universally occurring in all germ plasms. Thus, in various mammals that have been reared so that they can be observed, mutation has occurred in all visible parts, in internal organs, and in resistance to disease. In man, which is the mammal that has been most thoroughly studied, we have mutations in hairiness, pigmentation, skin growths, appendages and digits, teeth, sense organs, form of internal organs, like the iliocecal valve, size and functioning of the endocrines, structure and functioning of the nervous system, of the blood and of the reproductive system. Finally, we have mutations in disease resistance, due to obscurer morphological or biochemical idiosyncracies.

Among pigeons, mutations in color, form of beak, nervous behavior have arisen in the Whitman-Riddle series. In poultry, I have in the course of 10 years got apparently new mutations in toes, wings, and nervous reactions. And any poultry fancier knows of the mutations that have occurred in the past 75 years in color and pattern, in comb, in cerebral hernia and crest, in feet, wings and beak, and in egg-laying capacity.

In the insects which have been bred for rapidity of generations mutation has been repeatedly found. In *Drosophila*, Muller computes that among 500 factors in the X-chromosome of *Drosophila* each, in the average, mutates at the rate of one mutation in four years. This would seem to mean that, if you followed a single chromosome and when it divided considered one of the daughter chromosomes and so proceeded through the generations, then at the end of four years the expectation is that in this line of chromosomes some one gene will have mutated and at the end of four more years that gene, or some other in the chromosome line we are following, will have mutated again. But there is an infinitude of chromosomes in the totality of all *Drosophila melanogasters*. The number in a single gonad is vast; the number of gonads in the world of Drosophilas that swarm in the autumn over every mass of decaying fruit in a million of orchards as elsewhere is practically infinite. One sees that just *Drosophila melanogaster* is producing an infinitude of mutations each season, and it has been producing this infinitude annually for a long time; but time does not count for much, for infinity times a finite number remains infinity. *Drosophila* throws upon the world each year, a vast number of kinds of mutations in inconceivably great numbers.

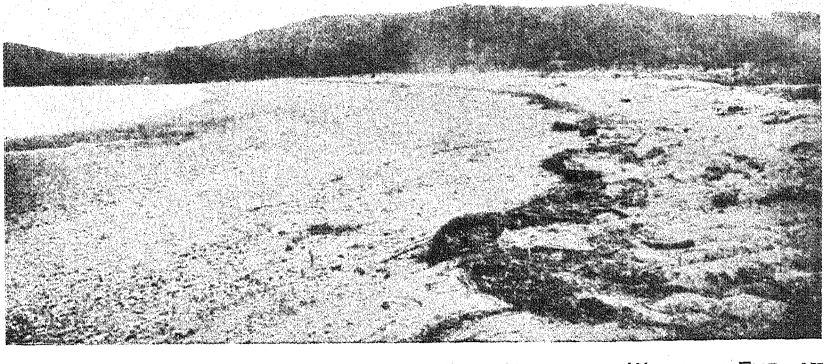
And *Drosophila* is not exceptional. Let us take a small water crustacean, one of the Daphnids. Banta has reared lines of these in captivity and examined the progeny daily. In one line of *Moina macrocopa*, carried parthenogenetically, a dominant mutation has occurred, on the average, at least once in 50 generations, but many more recessive mutations have occurred and been phaenotypically unexpressed. Now the number of Daphnids, which crowd any suitable pond in both hemispheres during each spring and autumn, is beyond conception. For a single circular pond a hundred feet in diameter may well contain during the season many million Daphnids, if one is allowed to the cubic centimeter. The total of mutations that occur in one year in *Moina macrocopa* must be inconceivably great.

Certain of the lower forms are mutating even more strikingly. At least such would seem to be the case if the remarkable variations shown by Leonian in the fungus, *Fusarium*, may be regarded (as seems most probable) as mutations. Here scores of strains arise, in but a few years, even in a uniform culture medium, and perpetuate themselves. The strains vary in their rate of growth, pigment formation, type of fruiting, kind of spores, and reactions toward temperature, acids, dyes, and toxic substances. Apparently such mutation is going on all the time in nature.

As we consider these best known cases of mutation and realize that all of the countless chromosomes and genes are undergoing occasional change we are appalled by the universality of mutation and are caused to wonder how any species remains constant in nature to the extent that it is possible for a second naturalist, 50 years later, to identify in nature the species already described; we are less surprised that the reviser of a genus a generation or two later will find twice as many species as his predecessor. We gain a lot of sympathy for the much abused species splitter who, observing nature without the restriction of tradition, finds vastly more species than had been previously described by his predecessors.

Organisms seem to be producing mutations at an inconceivably rapid rate, in infinite quantity The wonder is that there are such things as species. One is led to inquire if, in describing species, taxonomists are not merely inventing transient, evanescent categories.

Such a conclusion is unjustified. Every taxonomist will tell you that the things he describes and others have described before him are real entities. If I am studying thrips and wish to secure a species described 50 years ago as living in a certain composite plant in eastern Russia, then if I go to the designated locality and look in the designated species of flower I will find the species with all the characters described 50 or 100 thrips generations ago. How is such an experience in constancy to be harmonized with universal mutation? This is perhaps the heart of the problem of evolution.



PHOTOGRAPH OF NORTH SIDE OF SAND SPIT, NEAR THE WESTERN END, AT LOW TIDE. COLD SPRING HARBOR

In the central foreground is the high-tide line, marked by a mass of débris. On the left is the gravelly lower beach; the middle beach and storm bluff are at the right.

In considering the fixity of some species it must first of all be recognized that a species is a complex of morphological and physiological characters that can not exist alone but is absolutely dependent upon the external world for its existence. The organism must live in a medium of such and such physical qualities, at such a temperature, in the midst of such radiant energy, with access to such and such foodstuffs which it is capable of taking in and utilizing for its metabolism. Every organism is extraordinarily closely fitted to its environment. And that environment may be very complex.

I will illustrate this principle by reference to the almost microscopic Collembola that live on the beach at Cold Spring Harbor.

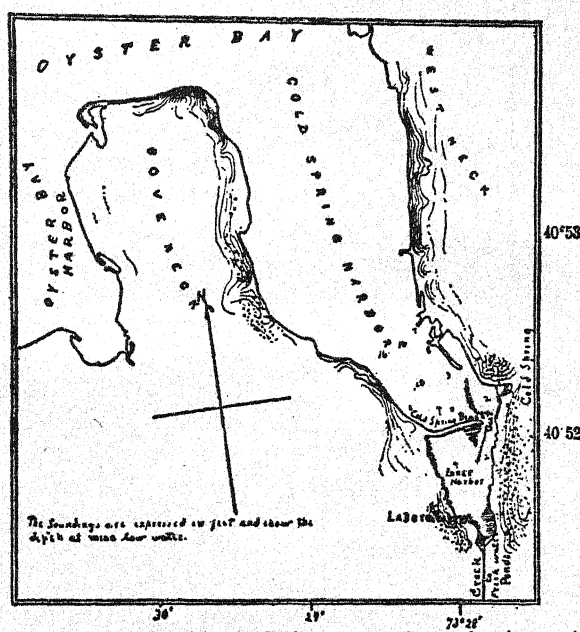



FIGURE 1.—Map of Cold Spring Harbor, showing spit (Cold Spring Beach)

(Fig. 1.) They live in an area of apparently washed sand and pebbles in a region that is covered twice a day several feet deep by sea water and then exposed to the air; in a region swept by strong winds, overlaid by ice in winter, and exposed to the hot sun's rays in summer. (Pl. 1.) A region where the sandy substratum is caused to shift by the action of waves, and its pebbles to roll. The region looks unpropitious for any organism, yet of one species of Collembola in an area a kilometer long and 5 to 8 meters broad there are probably in the middle of summer a hundred million individuals. And they are meeting successfully the difficult and complex conditions imposed by that particular habitat. If the habitat be compared

to a most intricate lock, the organism is a most intricate key that fits that lock completely. How has this key come to fit this lock?

First of all, it is to be said that the Collembola in question is the only larger organism that is found in any huge numbers on and in the great portion of the beach. Worms there are that live in the sand of the beach; crustacea and insects there are that feed on the débris that is thrown up by the sea at the high tide line; but it is only the Collembola that swarm over the beach. (Fig. 2.)

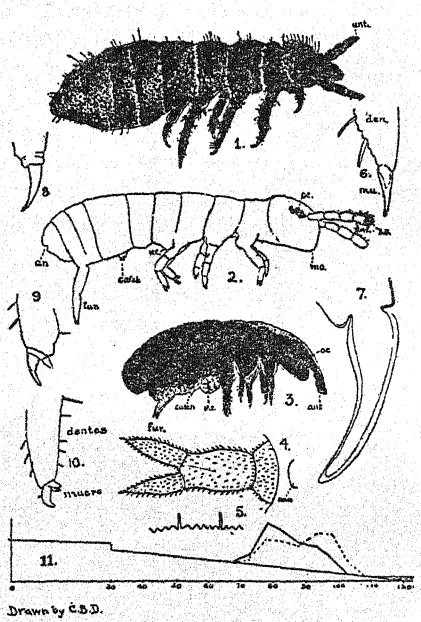



FIGURE 2.—Drawings of three species of Collembola on the beach, (1), (2), and (3), with some details of their structure; (11) shows the relative frequency of *Isotoma* on the beach; the abcissae represent distances from the beach line on top of the beach; the ordinates, the proportional frequency of occurrence

Why are the Collembola the only organisms that make such use of the beach? The answer seems to be that they are the only group that holds a key approximating the needs of the beach lock. Two other species of Collembola live on the edge of the beach, in relatively small numbers. But one, *Isotoma berselsii*, has the combination of small size, slender form, and greater capacity for jumping that are demanded for successful life on the beach. Another species which has a chunkier form and is less successful as a jumper is found on the beach but is much less numerous than the first. Now the Podurid Collembola have, in general, a structure and reactions that lead them to live in situations not so very different from those occupied by *Isotoma*. They are found on water or in humid earth or in moist caves, or in crevices of moist walls. If anything is to survive in the sand of the sea beach it must come out of a group with instincts and structure that make it possible and preferable to live in such places. However, the interstices of the sand of the beach are especially fine and the period of exposure to the air is so brief that the insect must have movements and responsiveness of such sort as will ensure adequate exercise and oxygenation of the tissues during the brief time that it is exposed to the air. Collembola, in general, have the right form of key; *Isotoma berselsii* has precisely the appropriate notches to fit the precise lock of the beach.

I have dwelt at length on the Collembola of the beach because they may serve to illustrate the principle that mutations become the characters of species and play a part in evolution *provided* they meet some demand of the environment; or, the other way round, a new mutation persists as a species character if it can find an environment to which it is suited.

This general principle is of wide application. In Banta's Daphnids there appeared a female whose young died on a cool day in the autumn. It was found that subsequent broods could be kept alive in an incubator at a higher temperature than that of the room. In short, an investigation of the temperature relations of these cold-sensitive young and their equally cold-sensitive descendants showed that there had arisen by mutation a thermal clone, a parthenogenetically reproducing strain, whose optimum temperature was about 10° C. higher than that of the ordinary Daphnids. This mutation was fatal at the ordinary room temperature; it had important survival value for the environment of an incubator; it would have had an important evolutionary value had there been a warm spring near by into which the strain could have been transplanted. This experience, indeed, shows the probable method by which aquatic animals have come to inhabit hot springs. It is not by gradual change wrought on the germ plasm by the direct action of the high temperature of the water, but rather the fine opportunity for survival afforded by the high temperature to any chance thermal mutant.

Again, as has long been known, many of the animals that live in caves are blind and much speculation has been offered to account for this blindness. The old idea was that, through disuse and the parsimony of nature that would prevent it from continuing to form useless organs, the useless organs were no longer formed. On the other hand, Eigenmann, through his extensive knowledge of fishes, was able to point out that the blind fish of caves belonged to just one family of fishes, a family that had mutated in the direction of blindness in various parts of the continent. Now, some of these mutations in the direction of blindness have survived even where there are no caves, but where there are waters running through densely wooded swamps and characterized by dark holes where poor sight is no handicap to the fish. When a blind mutation arose in that family of fishes living in the region of limestone caves of Indiana and Kentucky, that mutation was no handicap to its possessor. For the possessor had other sense organs sufficient to secure its prey. The waters of the cave, indeed, removed competition, and in other ways afforded an extraordinarily favorable environment for this genus of fish.

Another illustration may be afforded by still another group of animals. As you know there are vast numbers of mollusks living in the

sea and in fresh waters; clams, oysters, periwinkles, cuttle fishes, squids are familiar marine mollusks. But there is a group of mollusks that has a history quite as striking as that of the cave fish. This group lives on the land, and sometimes, in very dry situations, even semi-deserts. In this situation the mollusks breathe by lungs instead of gills. How have the land mollusks, the pulmonates, including the snails and slugs, come to live on the land? One explanation that has been offered is that some marine ancestors gradually moved into streams and higher up into ponds which dry up periodically and there became gradually modified to breathe air. The matter is not quite so simple. The river mussels live in streams and ponds that occasionally go dry; they perish under these circumstances by the million; and yet they have never become adapted to land life—the appropriate mutations have never been afforder. Our land snails are the end result of a long series of mutations that have permitted life on the land. The first mutations in this direction occurred in certain marine snails with a gill chamber whose opening is so small that it can readily be closed to prevent the ingress or egress of water. Any mutation in this direction would enable its possessor to enter into the between-tides zone.

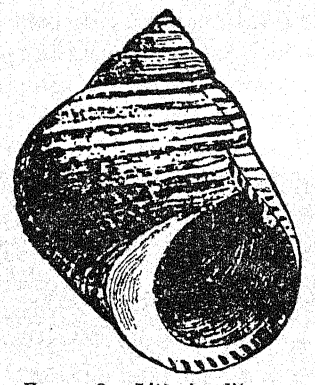


FIGURE 3.—*Littorina litorea*

Actually, there live on our shores shore-snails, belonging to the family of Littorinidae, inhabiting a level where they are exposed to air for 12 to 20 hours of the day. Indeed, among the Littorinas one finds species that differ greatly in their emancipation from the sea. During the recession of the tides the Littorina keeps the opening to its mantel chamber closed; so its gills are held in a medium saturated air. (Fig. 3.)

Now, it is out of this general group to which the Littorinas belong that the land snails have arisen. Any continued mutation in the direction of gill reduction or enclosure of the mantle cavity would have been in the direction that would have permitted the possessor to pass to dryer parts of the shore line and, incidentally, to escape from its enemies. The point is that not just any group of marine snails was able to adjust itself to land life, but only a group in which favorable mutations arose. The land crabs and the lung fishes represent the end stages of a similar evolutionary history to that of the land snails.

While it appears from these considerations probable that adjustment to extreme conditions of life has been rendered possible by

favorable mutations, it still remains to consider what light modern genetical studies throw upon the details of this process.

We have seen that reproduction is unlimited and that mutation is constantly occurring; not, to be sure, in infinite amount in all directions equally but abundantly in certain genes; more rarely in others. We have now to consider in turn what induces mutations; what gives direction to mutations; how are the adaptations in nature brought about?

First, the causes of mutation are clearly determined, in part, by the unstable nature of the gene itself. The genes are very complex molecules, or rather groups of molecules. Now, many complex molecules are known in chemistry that are so labile that they break down almost spontaneously. How many compounds have to be kept in the dark, at a low temperature, undisturbed in order that they may "keep" at all. In time they "spoil," even under the best of conditions. The rate of change may be accelerated by heat, light, and irradiation. The genes are not exceptions to the rule of change in labile substances. While the nature of the process of mutation in the genes has shown itself little influenced by external agents the velocity of spontaneous change is readily altered. Thus Muller, Hanson, and others find the speed of mutation accelerated by increase of temperature, and by X rays. No new mutations have been brought forth by the X rays, but mutation occurs more rapidly. The X rays do not direct evolution, or even mutation, qualitatively, but afford opportunity for more rapid evolution by providing, in larger amount, one of the factors—mutation—necessary to evolution.

The fact that X rays may accelerate the process of gene mutation has led some to the conclusion that all mutation is due to radiations. No doubt conditions compatible with the life of the soma may be found that will not permit of mutation, but it does not seem probable that this will ever be the case. Just the conditions essential to life probably provide the conditions for gene mutation.

Second, what gives direction to mutations? It is obvious that the organic world is far from being the infinitely diverse collection of haphazard and meaningless variants that we might expect were mutation entirely uncontrolled. It seems probable that, under ordinary conditions, genes break down or disintegrate in orderly fashion dependent on the nature of the gene. An illustration, which may be more than a mere illustration, is afforded in the rare earths where uranium breaks down into radium and radium into lead. Each stage, in turn, is determined by the immediately preceding stage.

So, in organisms, the mutations are usually of a recessive nature, which seems generally to imply that they are produced by a loss of something from the parental gene. In the different species of one

genus the same kind of mutations occur. Thus between *Drosophila melanogaster*, *D. simulans*, and *D. virilis* quite parallel mutations occur and are identified in many cases with genes occupying comparable loci in the chromosomes. Among mammals, with which we are naturally best acquainted, certain mutations occur again and again. Thus albinism, coat-color pattern, hairlessness, elongated hair, reversed hair, taillessness, abnormal hands and feet, particularly digits, horns or hornlessness, achondroplasia. The recurrence of these mutations in various species of mammals, as tabulated by Osborn (1912), indicates that mutations are far from haphazard in origin, but probably depend upon the same genes with the same structure and capacity for change.

Finally, the mutations with which we are familiar constitute only a fraction of those that occur. Every student of intrauterine stages of mammalian development is familiar with the phenomenon of intrauterine deaths. So far as our observations go, it appears that in mammals more young die *in utero* than are born. Every student of development of sea urchins and other marine organisms knows that a large proportion of those that start to develop do not proceed far. We see that early developmental stages are those in which great selection takes place; probably because the embryos carry nonviable mutations. From this point of view the individuals that reach maturity constitute the fraction that have undergone no lethal mutation.

The fact of lethal mutations (for they have been demonstrated in many cases) helps us to understand the other fact that in the midst of the world of mutations the organisms that come through are more or less well fitted to survive; they are not always the best, but they are good enough to pass the censorship of environment.

And this brings us to a consideration of the phenomenon which Darwin stressed, namely, of adaptation to environment. We have already seen that such adaptation is partly brought about through the selection by the organism of an environment that is adapted to it. We may now consider the case of selection by the environment of organisms that are adapted to it. In general, the organism must be able to play properly its part in the flow, in and out, of the chemical agents, water and foodstuffs, upon which its life and activity depend. It must be capable of meeting emergencies of climate and organic enemies. It must pass the censor at every stage or be squelched.

A little experience of my own, which I published some years ago, will serve to show how strict is this censor. I reared a large number of chickens to the 1-pound stage and had about 300 running over a grassy plot on about the tenth of May, at a time when crows are feeding their nestlings and hunting especially meat for them.

About 40 per cent of the birds had a white plumage, 40 per cent a black (or nearly black) plumage, and 20 per cent a plumage in penciled or striped markings, more or less like that of the ordinary game or the jungle fowl. Of these the crows killed 24. Expectation, on the basis of random attack on the birds, was that about 9.6 would be white, 9.6 black, and 5 penciled. Actually there were killed 10 white, 13 black or prevailingly so, and 1 coarsely mottled gray and buff. No truly penciled bird was killed. This observation tends to illustrate the principle that the self-colors in wild birds tend to be eliminated because conspicuous to their enemies; birds with mixed pattern are relatively immune from attack because relatively inconspicuous.

Now, though it has not been experimentally proven, yet the hypothesis may be entertained, that the presence of light-colored mice in limestone regions and of dark-colored mice on lava beds may result from an elimination of mutations that are in disharmony with the background. To nocturnal predaceous animals, like the owls which catch mice, a white or light-yellow mouse on a black lava bed would be seen and captured before a black one.

One further fact must be taken into account in considering the adjustment of organisms to their environment, and that is that change of environment may well cause and apparently has in the past often caused the elimination of species over the whole extent of their area of destruction.

Consider how widespread must have been the consequences on the fauna of the Northern Hemisphere as far south as Long Island and even further south of the great ice sheets that covered the circumpolar territory in glacial epochs. Many poorly clad species of mammals must have found the icy conditions insupportable; just as the mastodon and mammoth did. The change in environment may be of a more subtle sort. Thus the great size and herd instincts of the bison enabled it to develop enormously on the extensive plains of North America and rendered it more than a match for the Amerinds living in a stone age. Just this size and number wholly unfitted these mammals for the new environment of the aggressive agriculturally inclined white man armed with a rifle. Agriculture and free-ranging bisons could not coexist, and the rifle eliminated the mammals. So to-day the great size and aggressiveness of the large mammals of Africa are a challenge to the sportsman, and the future seems to spell extinction for them. Here we have to do with elimination resulting from what may be called a cultural evolutionary "mutation"—the rifle.

But man's part in evolution is not merely in the elimination of his large enemies, which he has all too thoroughly mastered, but in his struggle with the small and innumerable insects that threaten his

agriculture as it becomes more intense. The more successful and prolific an insect injurious to agriculture is the more certainly will it arouse man's destructive energies and the greater the certainty that the all too favorable mutation that is the cause of its success will be the cause of its elimination in whole, or part.

But mutations of a still more dangerous sort are threatening mankind, mutations in the world of organisms that live as parasites on the human protoplasm. With the more conspicuous of these parasites, external and internal, man has learned to cope. One by one the pathogenic bacterial diseases are being eliminated or reduced in frequency. But now we face still smaller parasitic particles, the filtrable viruses which are, at present, practically inaccessible to man. There seems to be reason to conclude that they are mutating also, and perhaps rapidly. The waves of influenza epidemics that pass round the world in periodic fashion assume slightly different aspects, show somewhat different symptoms, in successive visits. Those who are resistant to the one visitation may show slight resistance to the next. The selections of the past have left the stocks of the more crowded continental areas a hardy resistant people, far more so than the peoples of distant oceanic islands that had not undergone selection for resistance to the ultra microscopic parasites. When one contemplates the high mortality of the influenza epidemic of 1918 one realizes that notwithstanding this high resistance it is quite within the range of possibility that at some future time a mutation shall arise in these viruses such that no human protoplasm is protected against it or can protect itself against it. Then our boasted skyscrapers might become inhabited by bats and the safe deposit vaults of our cities become the caves of wild animals.

Whether or not this will occur in the future, the possibility brings home a realization of the fact that man is not merely looking on the process of evolution taking place around him but, as an organism, he is a part of that evolution; he is acting upon other organisms and being acted upon by them as well as by the inorganic world in which he lives. He is attempting a mastery of that world; and, indeed, upon such mastery his fate may depend. His ability to master that world depends upon his superior gifts of intelligence to see relations and to idealize new ones. How much farther man can go in this direction depends upon the capacity for development of the intelligence. There are those who warn us that we are approaching the limit and must sometime in the future wait for further human evolution to make further fundamental progress. To wait until nature affords the desired mutation may mean indefinite postponement. Can not man himself control his evolution? Two methods are open; one the production of new and better combinations of traits by appropriate matings. This is the method of the applied geneticist interested

in creating new and improved varieties. This is the method that is open to man also, if only some change in the social order may make it feasible to apply our knowledge to the improvement of the genetical combinations in mankind.

But still another way may be opened in the future; that is the acceleration of mutation by irradiation. The method is fraught with tremendous difficulties. The commonest effect of irradiation of the gonads is the production of defective, often happily nonviable, individuals. Whether the production of scores of defective strains to secure one line with a superior mutation is justified will have to be considered. But if man is to evolve he must not decline to use nature's tools of mutation, cross-mating, selective elimination while he seeks to become fitted to meet the requirements of an ever changing and ever more-demanding environment.

To sum up, then; the mechanism of organic evolution, as I see it, consists of the following processes:

1. Infinite capacity of the germinal material for reproduction.
2. Infinite capacity for mutation.
3. A finitude [2] of kinds of environments.
4. Extensive opportunities for dissemination of the mutant individuals over earth, permitting some of them to find an environment for which they are especially fitted.
5. As for the rest of the infinitude of individuals, nonmutant and mutant (beyond the number required for replacement)—elimination.

In a sentence, nature's mechanism of evolution includes the elements of: A finitude of kinds of environment, infinite reproduction, infinite mutation, infinite opportunity for new mutants to find appropriate environments, and elimination of all of the infinitude of other individuals that are not required for replacement.

*Homo sapiens* is only a natural species with a highly evolved hand and brain. This species has reached its lofty position in evolution by the processes described. It is proud of its control of nature in certain directions. Let it beware lest it think it can evolve further by a man-made formula that may suit its perverted desires but must eventually fail of permanent progress if opposed to the formula of nature.

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[2] Through a *lapsus calami* this was printed in The Journal of The Washington Academy of Sciences as "infinitude." It is the limitation of environmental set-ups compatible with life that makes the number of successful "species," though large, still limited.

# EXTRA CHROMOSOMES, A SOURCE OF VARIATIONS IN THE JIMSON WEED

By Albert F. Blakeslee
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[With 13 plates]

Variations in plants and animals are the building stones out of which the present wide range of agricultural and horticultural forms have been developed. Experimental study of the origin of these variations has been concerned chiefly with changes in the ultimate hereditary unit factors. The present paper, however, discusses variations which are brought about by changes in relatively large groups of factors contained in chromosomes. In this summary of the types that have been discovered in the Jimson weed (*Datura stramonium*), text and illustrations from earlier publications [1] have been freely drawn upon, but much is presented here for the first time.

What chromosomes are may be better understood from Figure 1, which is a diagram intended to represent a plant of the Jimson weed (*Datura stramonium*) with a single enlarged flower. It need hardly be pointed out to most readers that all parts of the plant—root, stem, leaves, and flowers—are made up of microscope units, called cells, roughly analogous to the building bricks of an architectural structure, and that in each cell there is a definite number of still smaller rod-shaped bodies called chromosomes. The name chromosome means merely "colored body," and was given to these protoplasmic rods because they became strongly colored when acted upon by certain dyes. At the right of the diagram in Figure 1 are shown three cells with chromosomes and in Plate 5 are shown chromosomes as they actually appear under the microscope. The student of heredity is interested in chromosomes because they are the bearers of the ultimate hereditary factors which are transmitted from parent to offspring.

The diagram might have been improved if, instead of rods, we had used narrow medicine vials and had filled each vial with a row

[1] Figures 1, 2, 3, and 4 and Plates 4, 5, 7, 8, 10, and 13, Fig. 2, are taken, mostly with modifications, from the Journal of Heredity, vols. 15 and 20.
Plates 6, 9, 12, and 13, Fig. 1, are taken, with some modifications, from Annals of the New York Academy of Sciences, vol. 30.

of different kinds of pills. The pills with different potencies might represent the ultimate hereditary factors, and the vials which held them might represent the chromosomes. The comparison is far from perfect, but at any rate the chromosomes are believed to contain each a single row of unit factors arranged like beads on a string. Although these factors are ultramicroscopic in size, their relative position in the chromosome may be determined indirectly by a number of methods.

Throughout the vegetative parts of the plant, there are two of each kind of chromosomes as shown diagrammatically at the right

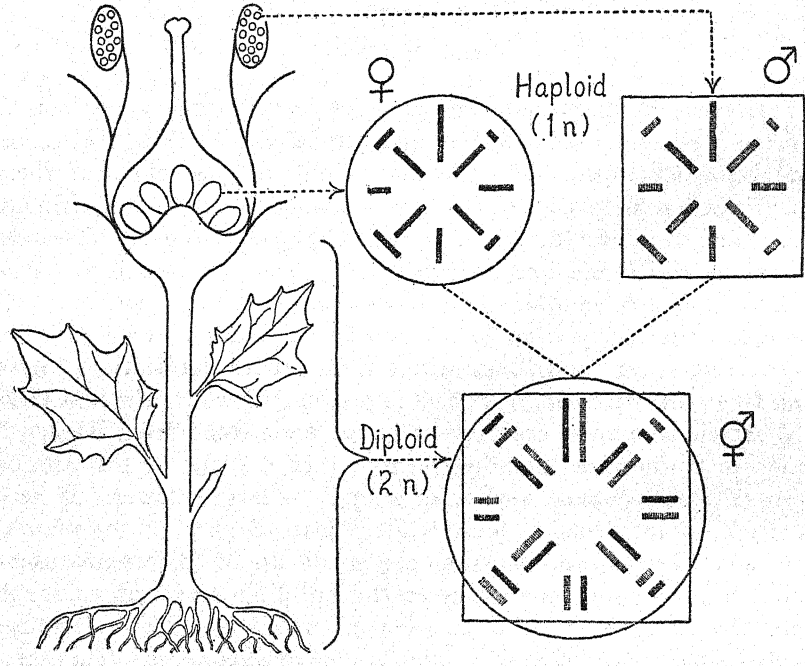



FIGURE 1.—Diagram of reproductive cycle in the Jimson weed. There are 12 kinds of chromosomes which are rod-shaped bodies carrying the hereditary factors. In cells of the vegetative (2n) part of the plant, each chromosome is present twice. In the male (♂) and female (♀) sex cells (1n), found in the pollen grains and ovules, each chromosome is present only once

of the bracket. Since there are two chromosomes in each of the 12 sets, this part of the plant is called the 2n or diploid stage. At every division of a cell in the 2n stage, each chromosome divides longitudinally into two bodies like itself, until the divisions preceding the formation of the sex cells.

Just before the production of the egg cells within the ovary and the pollen grains within the stamens, the chromosomes fail to undergo the usual process of division and one entire chromosome from each pair goes to each of the two daughter cells, thus reducing the number of chromosomes by one-half. In this "reduced," hap-

loid, or 1n stage there is only a single chromosome in each set, as shown in the diagram. According to the conventional use, a circle represents the female sex cell and a square the male sex cell. After pollination, when the pollen tubes have grown down to the ovary and have let out the male sex cells, fertilization takes place by the union of the latter with the egg cells. The result of fertilization is a seed in which the number of chromosomes is doubled. We come again, therefore, to the 2n or diploid stage.

All the higher plants and animals show this distinction between a 2n stage, in which there are two chromosomes in each set; and a 1n stage, including the sex cells, in which there is only one chromosome in each set. The number of sets, however, varies widely among the different species, although constant for any given form. Thus in the fruit fly there are 4 chromosomal sets, in man 24 sets, in the nightshade 36 sets, and in the Jimson weed 12 sets. In many species there is no visible difference between the individual chromosomes, although the breeding evidence may prove that they carry different factors. In the Jimson weed, however, size classes can be distinguished, as shown diagrammatically in the figures. Some of the chromosomes are further distinguished by presence of humps. It should be pointed out that, although the diagrams show roughly the relative sizes of the chromosomes, the arrangement is purely diagrammatic. The point to be emphasized is the grouping of the chromosomes into 12 separate sets although their association into such sets can be seen only in the cells immediately preceding the reduction division.

## ABNORMAL ARRANGEMENT OF CHROMOSOMES

While no change in the number of 12 chromosomal sets is known to have taken place in the Jimson weed, a considerable variation in the number of chromosomes within the sets may occur. Some of the chromosomal types that have been identified are shown diagrammatically in Figure 2. Since these diagrams represent the condition in the adult plant, only the diploid (2n) condition is normal. The plants are classified into balanced and unbalanced types according to whether or not all the sets have the same number of chromosomes.

## BALANCED CHROMOSOMAL TYPES

Balanced types may be still further divided into even-balanced or stable, and odd-balanced or unstable types. The former have an even number of chromosomes in each set, form sex cells with half the number of chromosomes, and hence breed essentially true. The latter have an odd number in a set, and are, therefore, unable to form sex cells with an equal division of chromosomes, and hence can not breed true.

Mature plants of 1n, 2n, and 4n types are shown in Plates 1, 2, and 3.

Flowers, floral parts, and capsules of the balanced types are shown in Plate 4. An increase in size of cells and organs of the plant is the rule in going from 1n to 4n forms, as is seen in the flowers in the photograph. In comparison with normals (2n), the leaves of 1n plants are very narrow while those of 4n plants are very broad. The

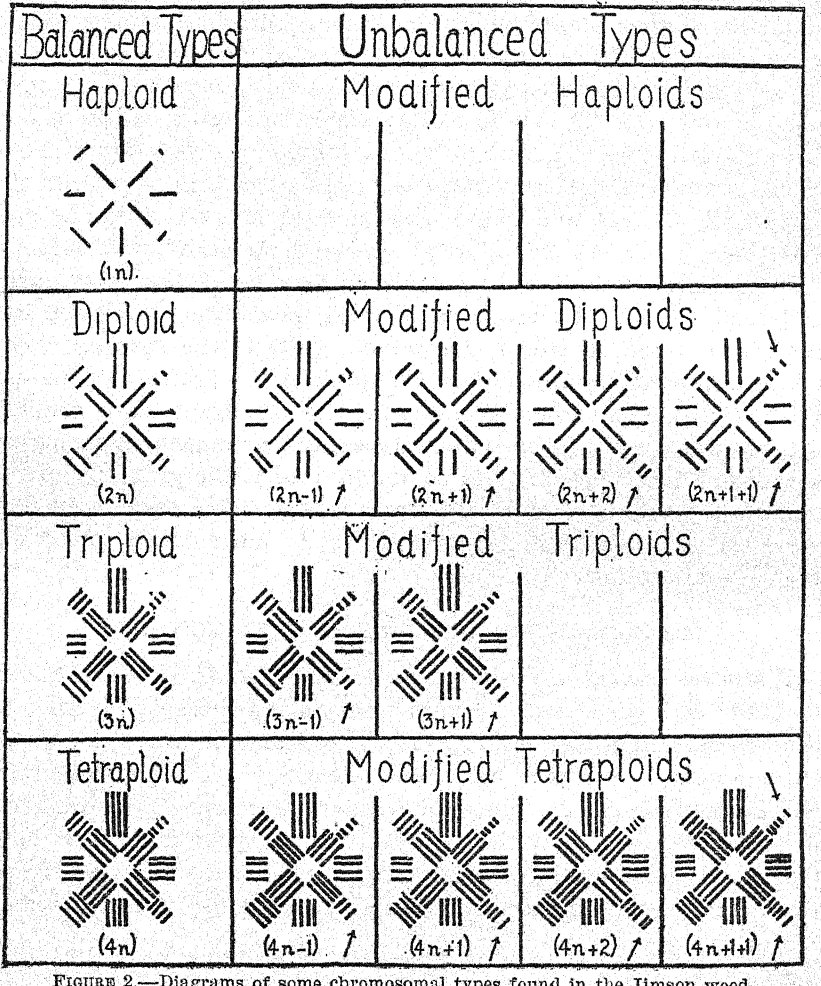



FIGURE 2.—Diagrams of some chromosomal types found in the Jimson weed

4n capsule is broader and more nearly spherical than the 2n capsule. It will be noted that the odd-balanced 1n and 3n capsules are much reduced in size, probably because of the small number of seeds which they contain.

Because 1n and 3n plants produce such a scanty yield of capsules and seeds, they continue blossoming long after the normal (2n) and

the 4n plants have become set up with capsules and ceased flowering. The 1n and 3n types, therefore, are of floricultural value in species in which it is possible to have a continuation of flowering by reducing seed production. Since such unstable balanced types can not breed true it would be necessary to propagate them by vegetative methods such as by grafts, cuttings, bulbs, etc.

Tetraploids (4n) are of horticultural value from the large size of their flowers. To the plant breeder they are of value as the means of obtaining triploids (3n). The cross 4n x 2n produces 3n or triploid individuals. From the latter may be obtained a wide range of types with extra chromosomes as will be shown later.

### UNBALANCED CHROMOSOMAL TYPES

In the unbalanced chromosomal types not all the chromosomal sets have the same number of chromosomes. Some of the types are shown in the diagrams in Figure 2. The simplest type is a modified diploid or 2n plant with an extra chromosome in one of the 12 sets. For comparison, diagrams of the chromosomes of a normal 2n plant from our standard line 1 are shown in Figure 3. All except two are in outline only. We will center our discussion upon these two chromosomes. The largest (*L*) for convenience may be called the white chromosome, and the small, medium one without the hump (*m*), which is stippled in the diagram, will be called the stippled chromosome. One half of each of these chromosomes has been shaded to distinguish it from the other half. The outer ends of each half are marked by a black dot. Models of the same chromosomes are shown in Plate 5.

The ends of all the chromosomes in the Jimson weed have also been designated by numbers 1 to 24. Thus the white chromosome, which is the largest of the 12, is numbered 1·2. Similarly the stippled chromosome is represented by the numbers 17·18. In all cases the odd number corresponds to the shaded half of the models.

### PRIMARY, SECONDARY, AND TERTIARY (2N+1) TYPES

If to the set of two white chromosomes, an extra member (1·2) like the other two is added as shown by the models (pl. 5 *A*), we have a (2n+1) type of distinct appearance represented by our "Rolled" mutant. From the peculiarities of this type we may learn something about the aggregate of factors contained in the white chromosomes. A type, named "Sugarloaf," is known in which the chromosome added to the white set consists of two unshaded halves (2·2) joined together as shown in Plate 5 *B*. The characters of the mutant type which results tell us something about the factors in the unshaded (or 2·2) half of the white chromosome. A type, named "Polycarpic," complementary to that just discussed, has the extra

chromosome made up of two shaded halves (1·1) (pl. 5 *C*). This type gives us information regarding the factors in the shaded (or 1·1) half of the white chromosome.

A type with the extra chromosome like the other two in the set is called a *primary* type in distinction from *secondary* types, in which

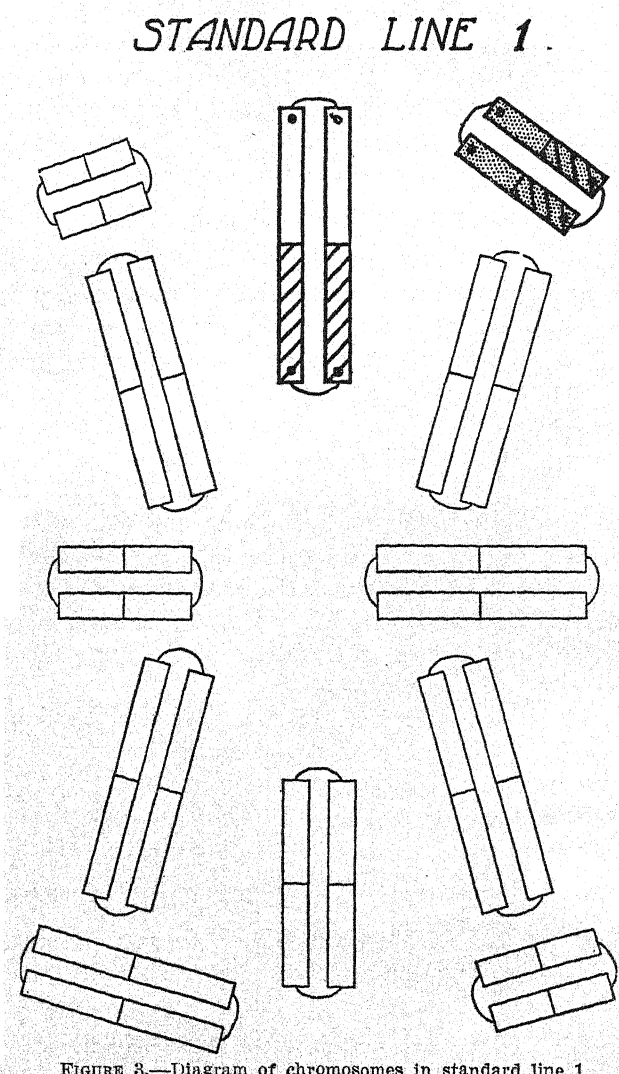
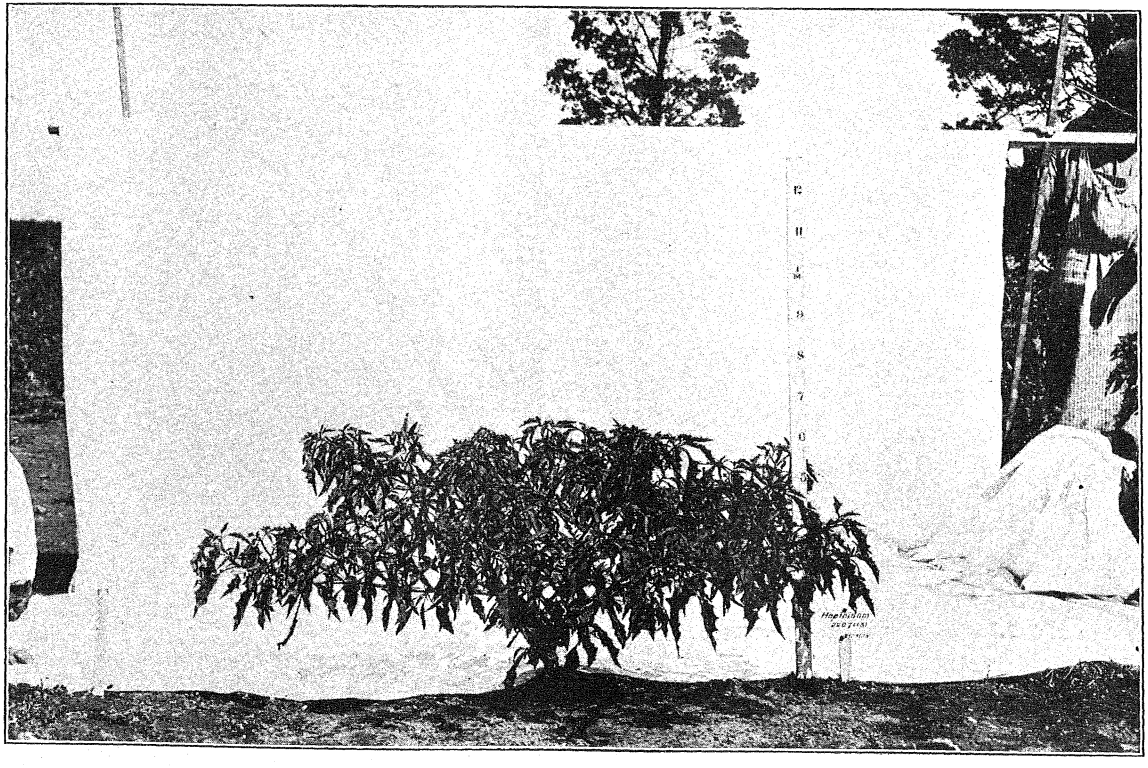
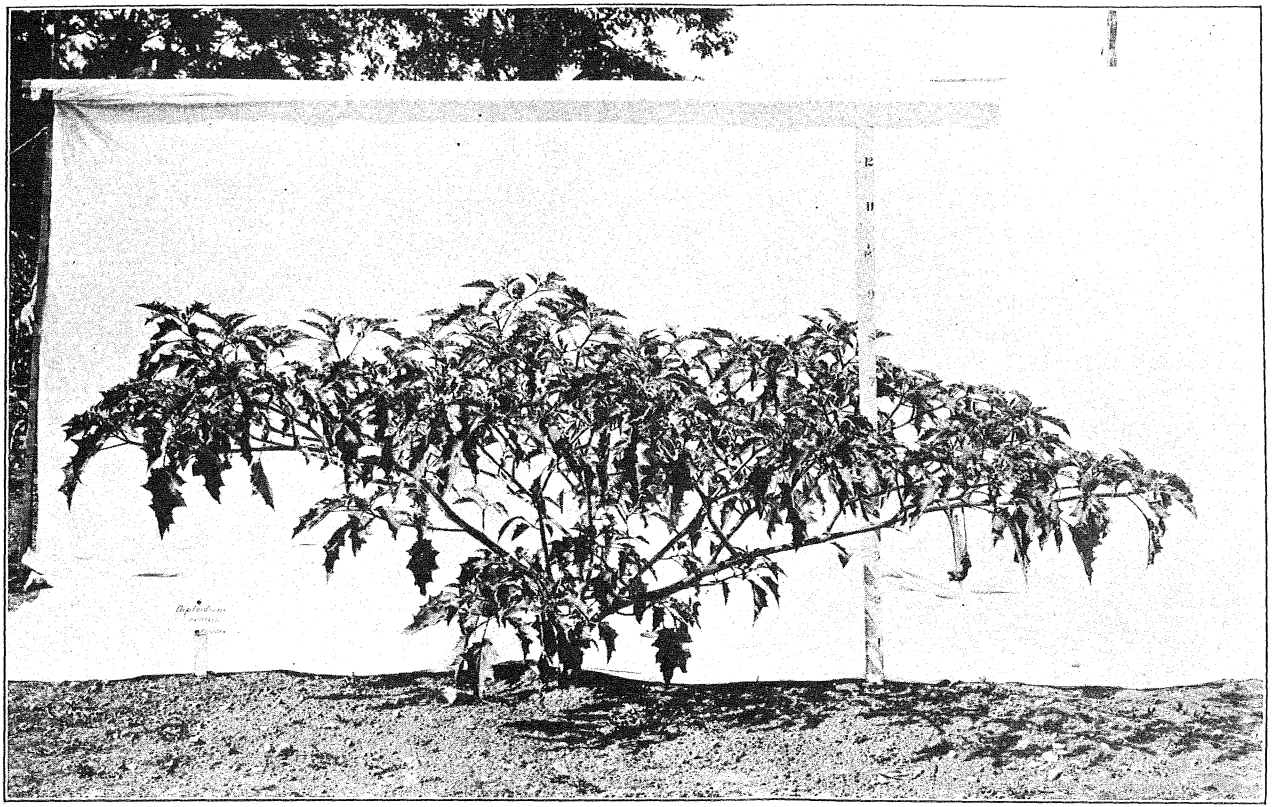



FIGURE 3.—Diagram of chromosomes in standard line 1

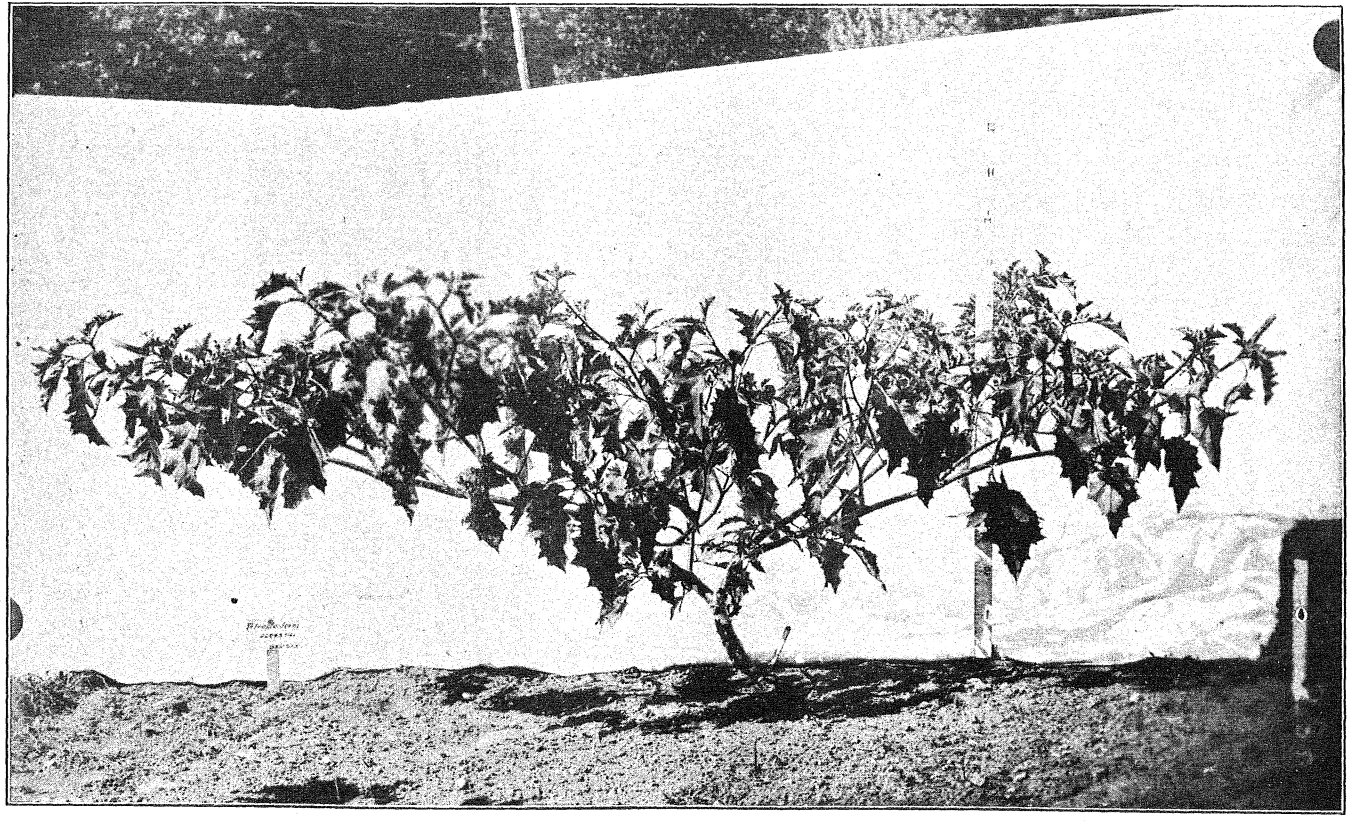
the extra chromosomes have been formed apparently by a breaking into two of a normal chromosome and a joining together of like halves. In the models we have not shown how the chromosomes in the trisome, or set of three, are attached together in the reduction divisions. Plate 5 *A*, *B*, *C* shows the appearance under the microscope of the chromosomes of the primary and the two secondaries of



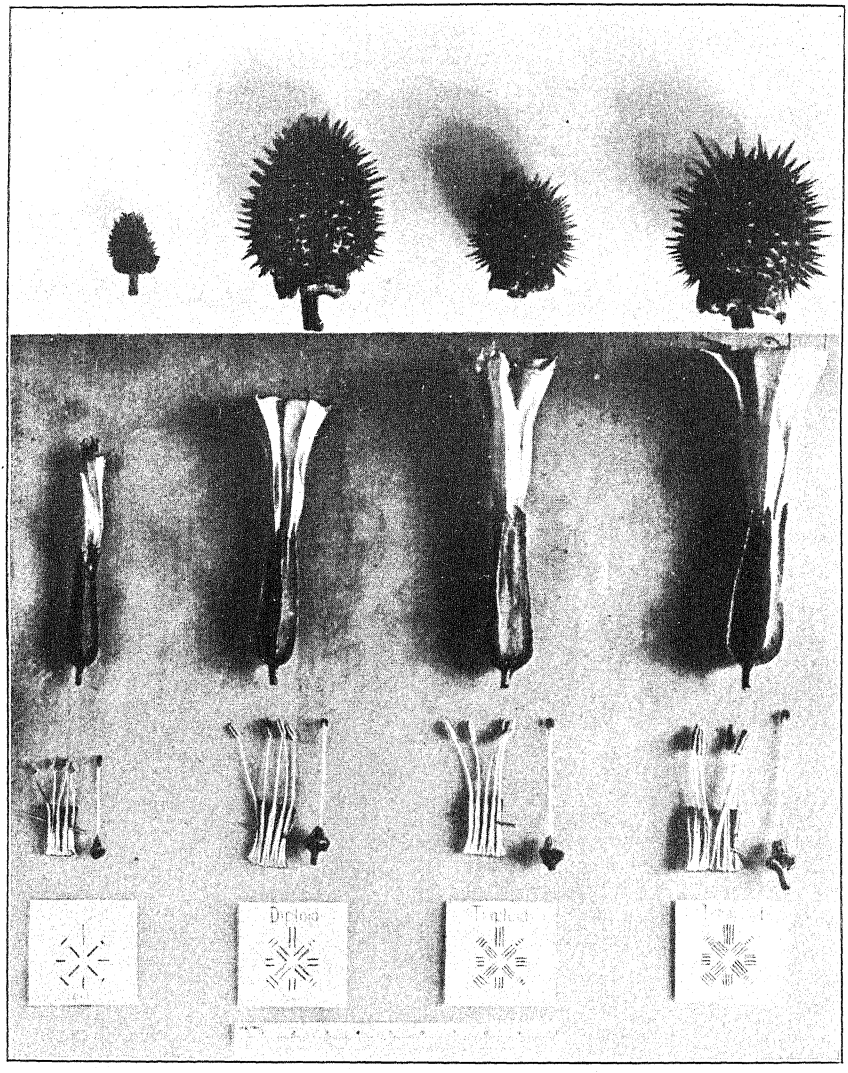
A HAPLOID (1N) DATURA



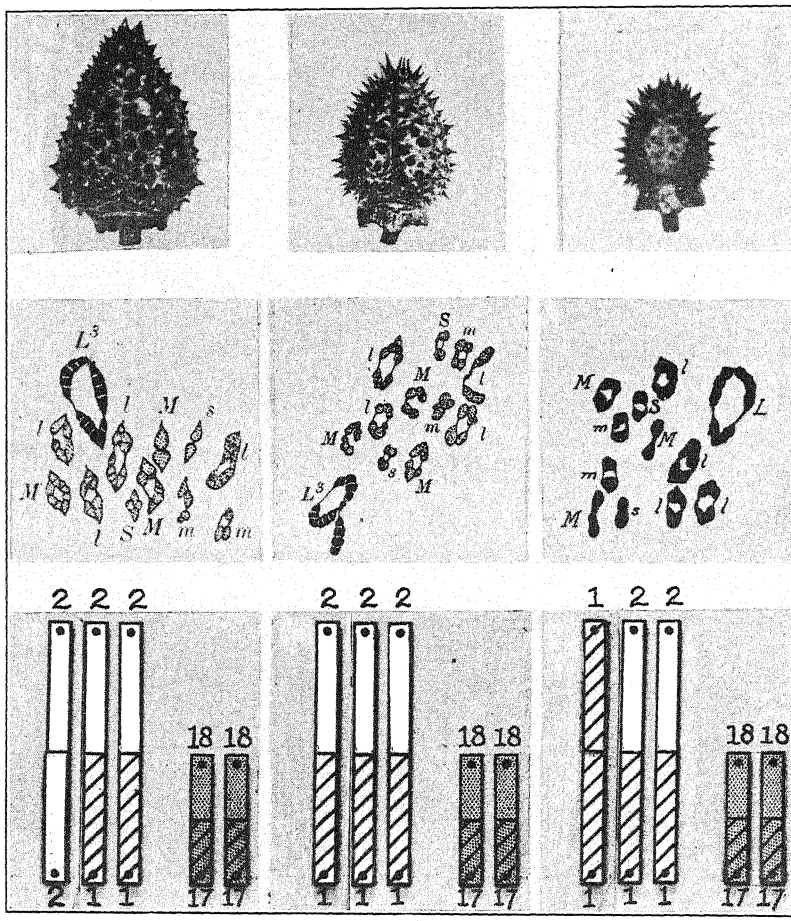
A NORMAL DIPLOID (2N) DATURA



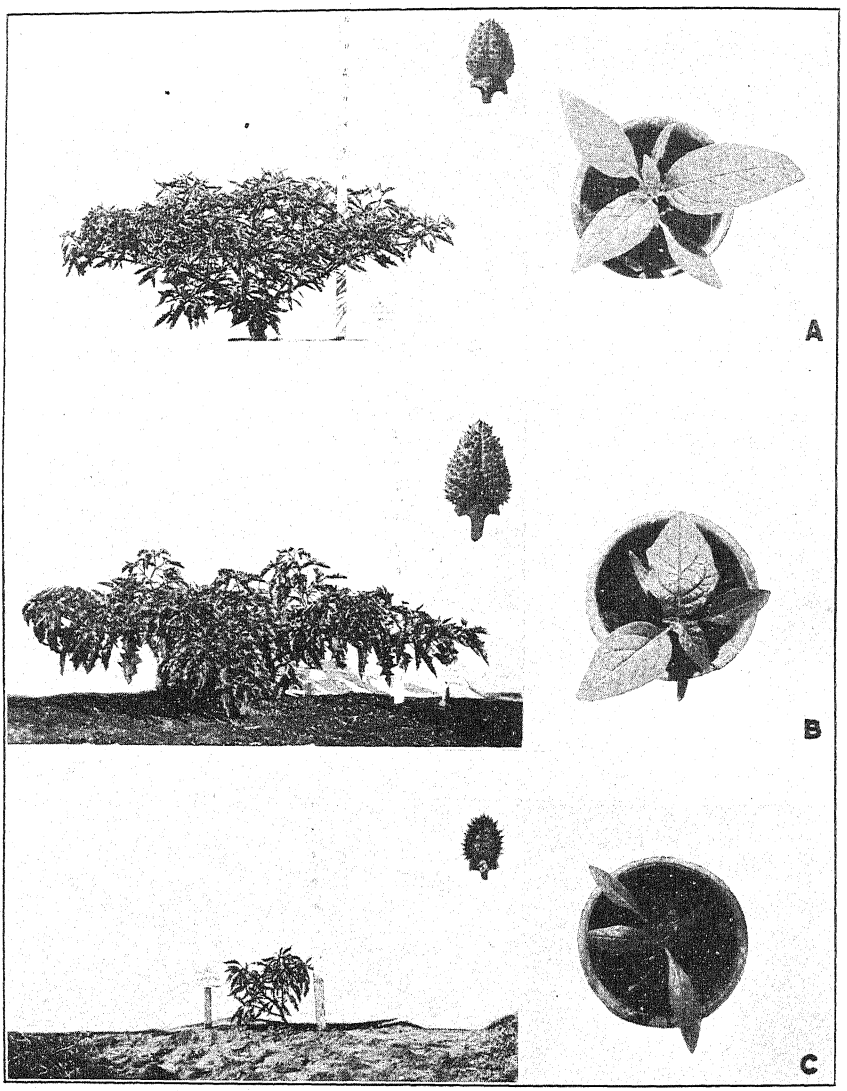
A TETRAPLOID (4N) DATURA



FLOWERS AND FRUITS OF BALANCED CHROMOSOMAL TYPES

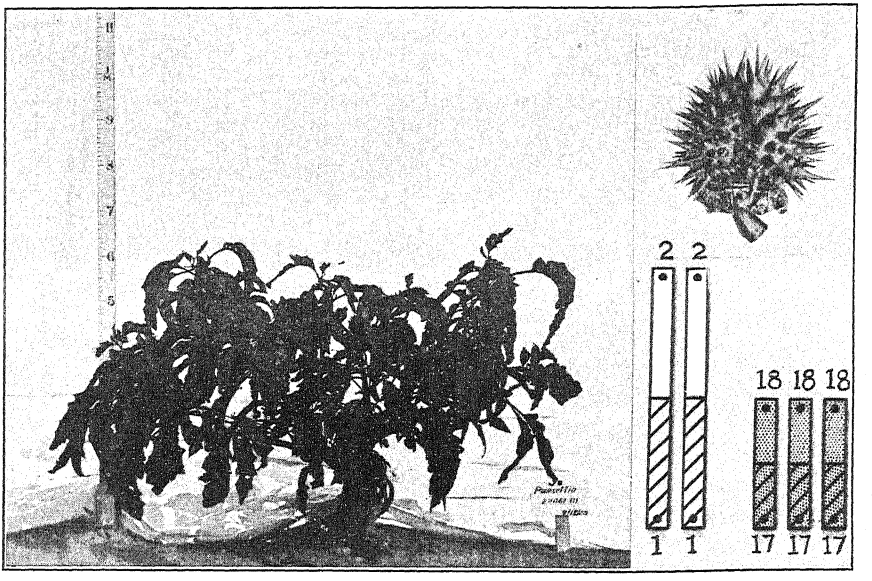



Upper row, capsules. Middle row, drawings of chromosomes as seen under the microscope. Lower row, models of the L and m chromosomes of a primary (2n+1) type and its two secondaries. A is the primary "Rolled" with the 1·2 chromosome extra; B is its secondary "Sugarloaf" with the 2·2 chromosome extra; C is the secondary "Polycarpic" with the 1·1 chromosome extra

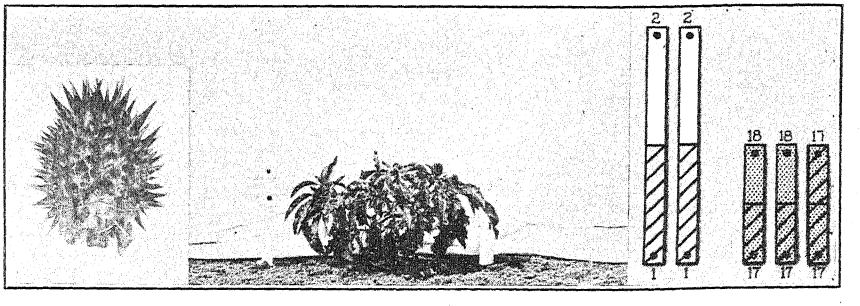



MATURE PLANTS, CAPSULES, AND SEEDLINGS

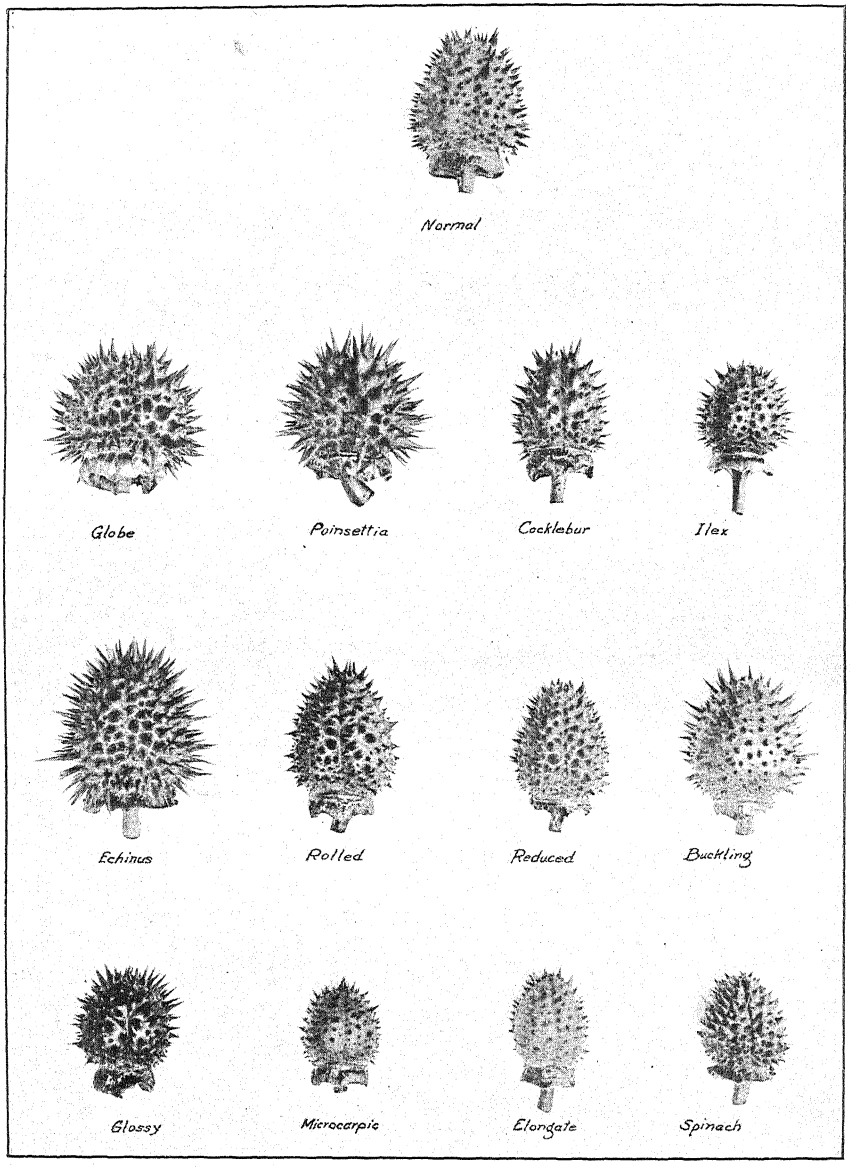
A, The primary (2n+1) type "Rolled"; B, its secondary "Sugarleaf"; C, its secondary "Polycarpic."



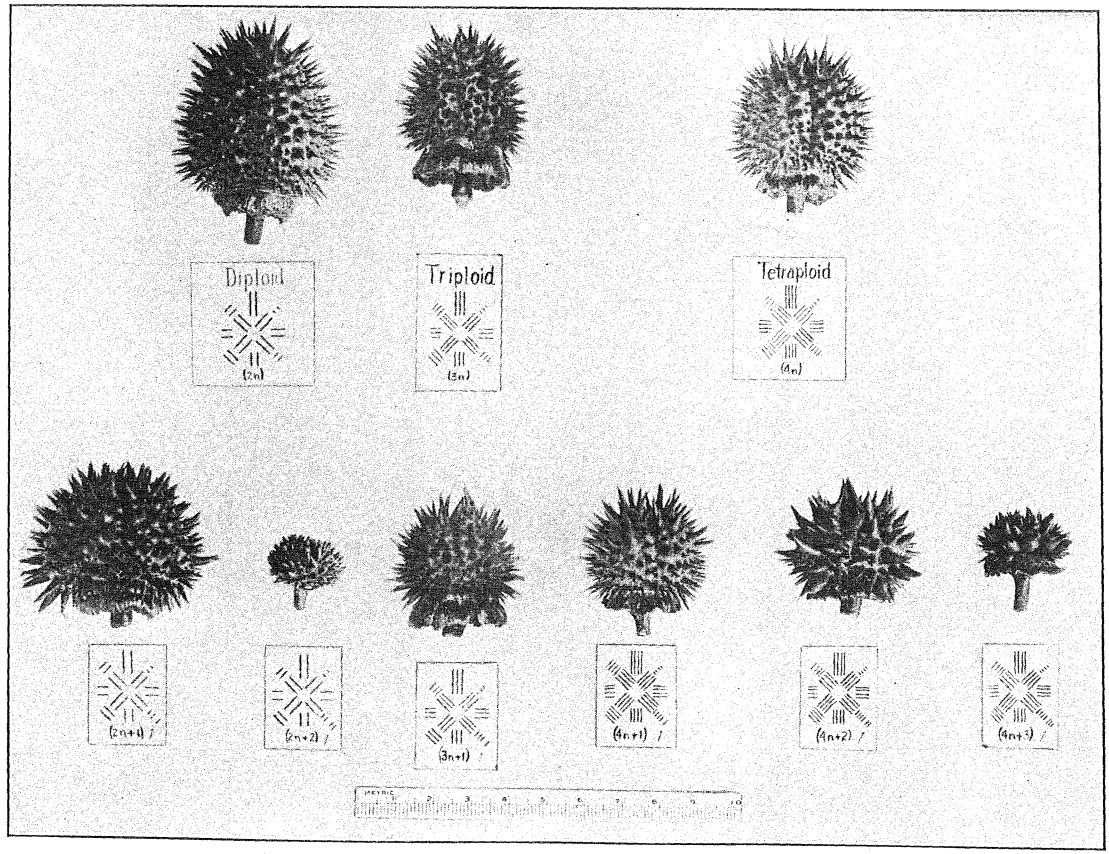

1. MATURE PLANT, CAPSULE AND CHROMOSOME MODELS OF THE PRIMARY (2N+1) TYPE "POINSETTIA"




2. MATURE PLANT, CAPSULE AND CHROMOSOME MODELS OF "DWARF," A SECONDARY OF THE PRIMARY "POINSETTIA" SHOWN ABOVE

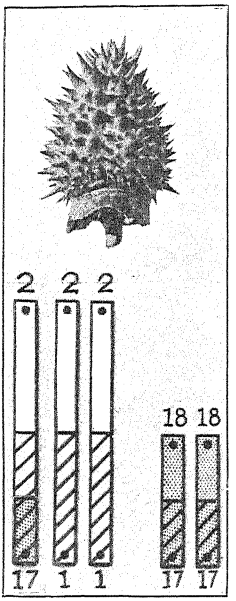



CAPSULES OF THE 12 PRIMARY (2N+1) TYPES IN THE JIMSON WEED WITH A CAPSULE OF A NORMAL PLANT ABOVE

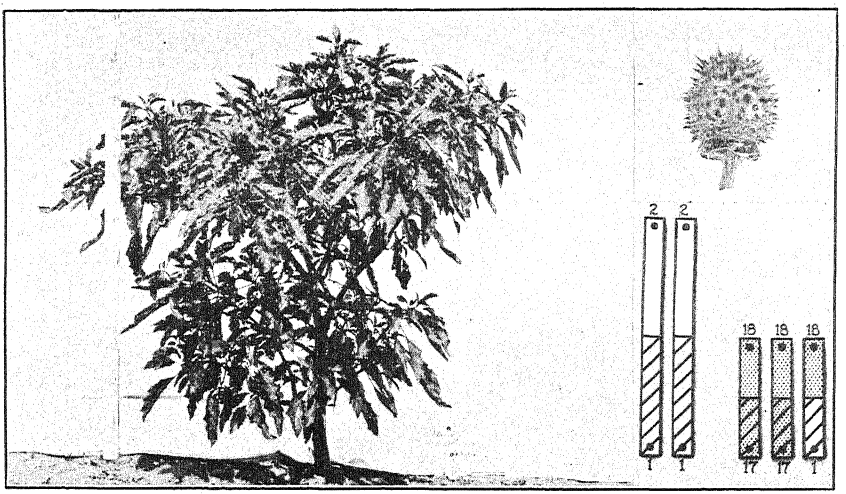



CAPSULES OF SIX "GLOBE" TYPES

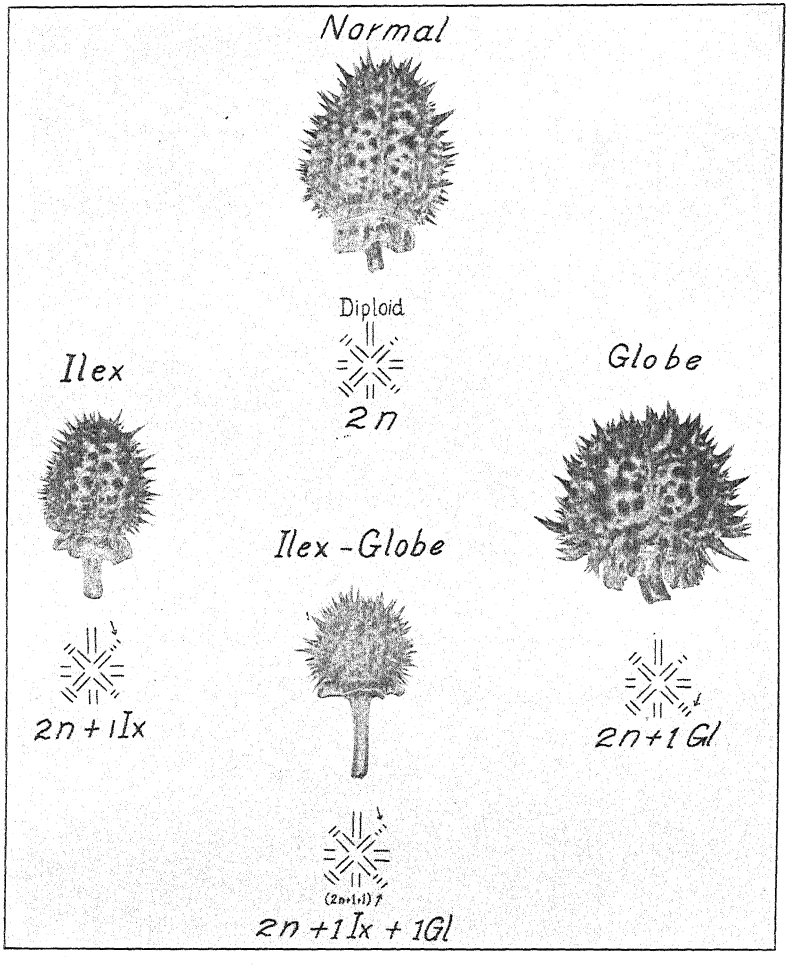
Normal diploid (2n), triploid (3n), and tetraploid (4n) capsules are shown above. Below, on left, are two diploid Globes with, respectively, one and two extra chromosomes in the Globe set. On the right are three tetraploid Globes with, respectively, one, two, and three chromosomes in the Globe set. In the middle is a triploid Globe with a single extra chromosome in the Globe set.



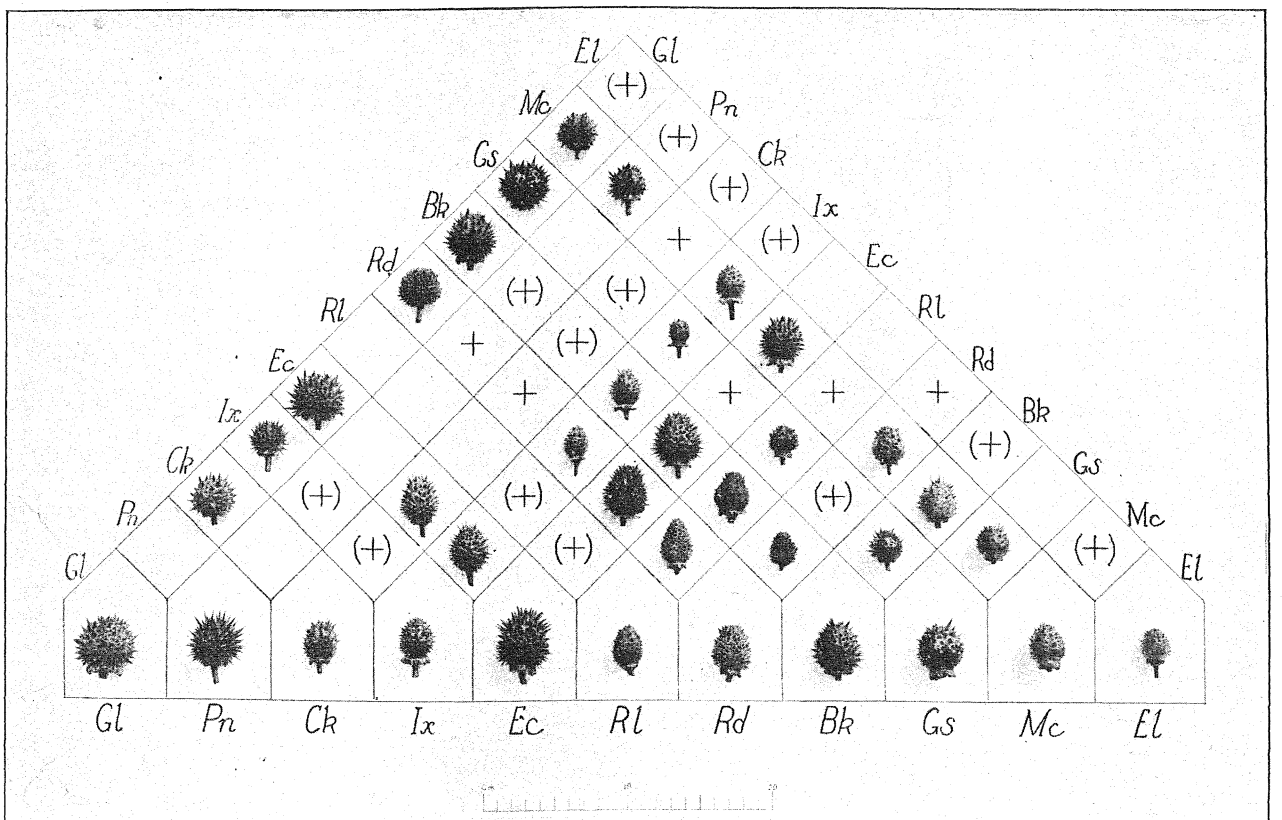

1. CAPSULE AND CHROMOSOMAL MODELS OF "DWARF SUGARLOAF," TERTIARY (2N+1) TYPE WITH THE 17·2 CHROMOSOME EXTRA




2. MATURE PLANT, CAPSULE AND CHROMOSOME MODELS OF "WIRY," A TERTIARY (2N+1) TYPE WITH THE 1·18 CHROMOSOME EXTRA

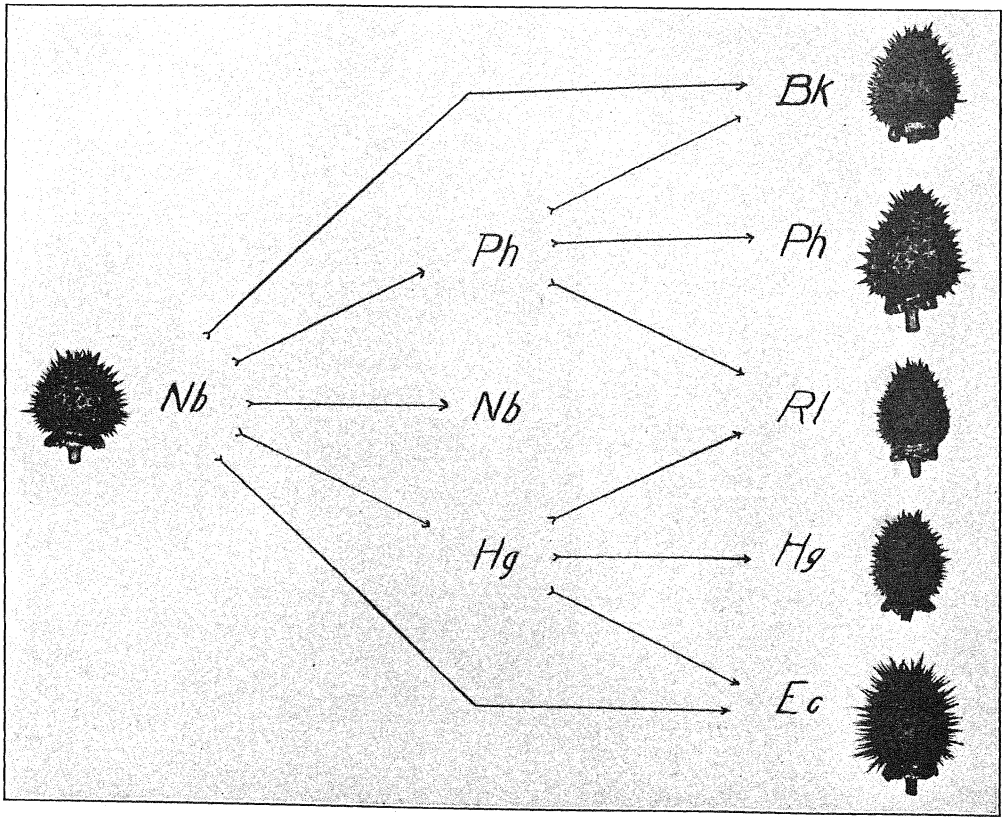



Capsule of normal diploid (2n) above; capsule of "Ilex" (2n+1 Ix) at left; capsule of "Globe" (2n+1 Gl) at right and capsule of double type "Ilex-Globe" (2n+1 Ix+1 Gl) below. Below each capsule is given its chromosomal diagram

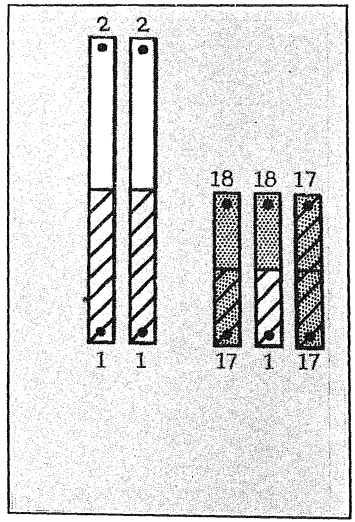



PRIMARY AND DOUBLE CHROMOSOMAL TYPES IN THE OFFSPRING OF TRIPLOID (3N) PARENTS

Lower horizontal row contains capsules of 11 of the 12 primary (2n+1) types. Diagonal rows contain capsules of double (2n+1+1) types each of which has two extra chromosomes in different sets corresponding to the extra chromosomes in the two respective primaries listed at the ends of the intersecting columns. Crosses indicate plants identified for which no capsules were available when photographs were taken (1925). Crosses in parentheses indicate plants of double types discovered later.




1. Capsules of compensating type "Nubbin" (Nb) together with tertiary types, "Pinched" (Ph) and "Hedge" (Hg) and the primaries Bk, Rl, and Ec. Arrows point to extra chromosomal types produced in the offspring




2. Models of a compensating type in which compensation occurs between a 17 half of the secondary 17·17 chromosome and the 18 half of the tertiary 1·18 chromosome

the white set. Those of Rolled and Sugarloaf are taken from Belling's figures, those of Polycarpic were drawn by Doctor Bergner. Since only like ends may become attached, the trisome of secondaries may form a closed ring of three, but the chromosomes of a primary never can form such a closed configuration.

Plate 6 *A*, *B*, and *C* shows mature plants, capsules, and seedlings, of the three (2n+1) types under discussion.

If we compare the primary Rolled with its two complementary secondaries, Sugarloaf and Polycarpic—all three the result of single extra chromosomes in the white set—we will note that each secondary is extreme in certain characters while the primary is intermediate. Thus, in Sugarloaf the capsule is large, a peculiarity due to the unbalance brought about by two extra unshaded halves of the white chromosome. In Polycarpic, the other secondary, the capsule is small, a fact resulting from the presence of two extra shaded halves. The primary Rolled, having extra both the shaded and the unshaded half of this same white chromosome, is intermediate in capsule size and shape.

Similarly from the habit photographs (pl. 6) it will be seen that the secondary Polycarpic is erect and has very narrow leaves. The complementary secondary Sugarloaf is spreading and has broader leaves. The primary Rolled is intermediate in respect to both these characters.

In a similar manner in the stippled set, we have a primary type called "Poinsettia" (pl. 7, fig. 1) due to an extra stippled (17·18) chromosome and a secondary type called "Dwarf" (pl. 7, fig. 2) due to the presence of an extra made up of two shaded halves (17·17) of the stippled chromosomes. The secondary with an extra made up of two unshaded halves of the stippled chromosome (18·18) has not yet been discovered. Possibly it is not viable. From the characters of the primary we know something of the factors in the whole stippled chromosome and from the characters of the single secondary (17·17), we know something of the factors in the shaded half. By subtraction we can gain some idea of what characters the missing secondary should show when discovered and hence of what the factors are in the unshaded (18) half of the stippled chromosome.

Photographs of the capsules of the 12 primary (2n+1) types in the Jimson weed are given in Plate 8 below that of a normal (2n) capsule. It will be noted that all are different. Capsules of the secondaries are distinct from those of their primaries as well as from those of other secondaries. Extra chromosomes have similar effects upon other parts of the plant. Extra chromosomal material thus brings about distinct and specific changes in the appearance of the plant in which it is present. This it does because of the genetic

factors which the extra material contains. It will be noted from our previous illustration (pls. 5 and 6) that there must be a different set of factors in the two halves of the 1·2 chromosome since the secondary Sugarloaf, which has the 2·2 chromosome extra, does not resemble the secondary Polycarpic, which has the 1·1 chromosome extra. In no chromosome does there appear to be a greater similarity between the groups of factors in the two halves than between the groups of factors in two different normal chromosomes.

The unbalance which extra chromosomes exert over the normal balanced condition may best be shown by capsules of the "Globe" mutants. The Globe chromosome is next to the smallest of the 12, but the changes which it brings about when present in excess are very distinct. As shown in Plate 9, we have two diploid (2n) Globes, or, more properly speaking, two diploids modified by extra chromosomes in the Globe set. The (2n+1) Globe has one extra chromosome in the Globe set giving an unbalance of one over the normal complement of 24. The (2n+2) Globe, with two extra chromosomes in the same set, has a greater unbalance (2 over 24) and in consequence all Globe characters, such as depression of the capsule, are heightened in expression. In similar manner starting with the capsule of a tetraploid at the right, it will be seen that the tetraploid Globes have their capsules relatively more depressed and their spines relatively stouter as we pass from (4n+1 ) to (4n+2) and (4n+3) Globes. A (4n+4) Globe has not yet appeared in our cultures, but we might expect it, since the unbalance which its extra chromosomes exert would be 4 over 48 which is the same unbalance found in the (2n+2) Globe (2 over 24). Similarly we might expect a haploid (1n+1) Globe with an unbalance of 1 over 12, but this unbalance, found as yet only in the rare (2n+2) Globes, may be the limit of unbalance which a plant can endure, and may be possible only in the diploid series. In the center of the picture we have a (3n+1) Globe obtained by crossing a (4n+1) Globe with a 2n pollen parent.

We have discussed primary or unmodified chromosomes and secondary chromosomes in which the two ends are alike. A (2n+1) type appeared not infrequently in our cultures which was neither a primary nor a secondary type. It always came from hybrids between our standard line 1 and certain "B" races. From the attachment of the extra chromosome to both the white (1·2) and the stippled (17·18) chromosomes, Belling concluded that the extra chromosome consisted of part of the white and part of the stippled chromosome. From these findings he proposed the hypothesis of interchange between segments of these nonhomologous chromosomes to account for the origin of "B" races from the standard type. The chromo-

somal diagram of such "B" races is shown in Figure 4. It will be noted that all except the white and the stippled chromosomes are the same as those in our standard line 1 (Fig. 3). There is no necessary difference between the two races, in respect to the factors which these

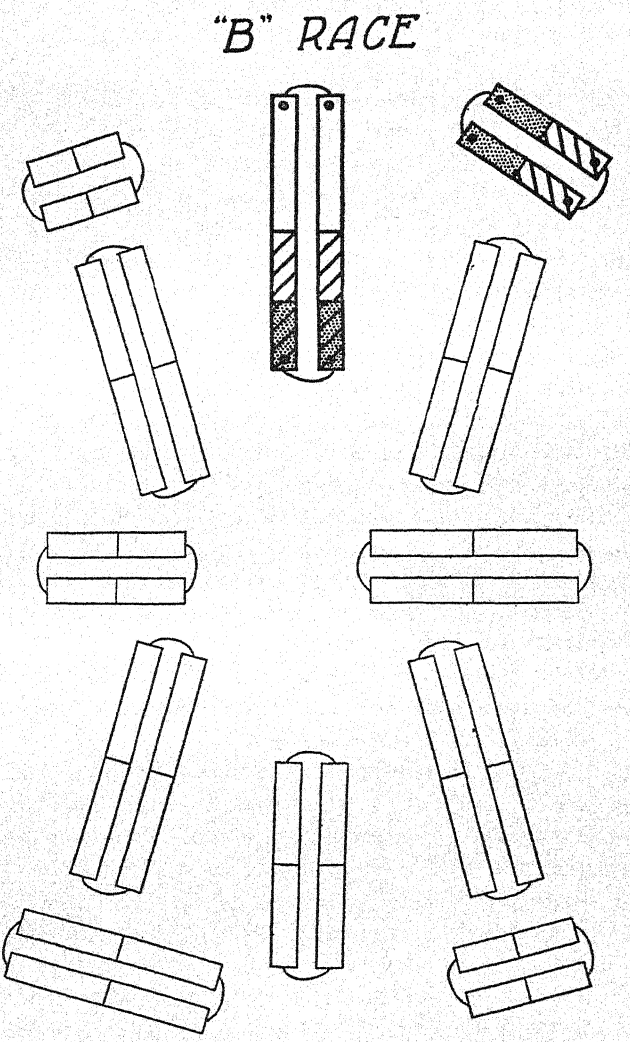



FIGURE 4.—Diagram of chromosomes of the "B" race. The stippled chromosomal material is part in the L chromosome and part in the m chromosome. In the standard line 1 (of figure 3), the stippled material is all in the *m* chromosome

two chromosomes contain. The grouping of these factors merely is changed. If its *L* chromosome were extra in a plant of the "B" race, it would form a primary (2n+1) type of this race. It is convenient, however, to use our line 1 as a standard and to classify types

in reference to this single highly inbred line. The two interchanged chromosomes, when added to line 1 diploids (2n), produce (2n+1) tertiary forms. "Wiry" (pl. 10, fig. 2) is a tertiary with the 1·18 chromosome extra and "Dwarf Sugarloaf" (pl. 10, fig. 1) is a tertiary with the 17·2 chromosome extra.

Three other types of races have been found in nature in which two chromosomes differ from those in line 1 by interchange of segments. Each of these races should give two tertiary (2n+1) types when properly combined with our standard line 1.

In Table 1 (p. 449) are summarized the (2n+1) types thus far identified, together with the factors (genes) already located in particular chromosomes. The chromosomes are recognized microscopically first by size and designated by the initials of the adjectives Large (very), large, Medium (+), medium (−), Small and small (very). Special modifications (humps) serve secondarily to further distinguish chromosomes of the same size.

In mutations called primary (col. 3) an extra chromosome is added to 1 of the 12; this is like the other two of the group of three (trisome) thus made. Its two ends are designated by numbers. In mutations called secondary the extra chromosome is made up by the doubling of only one-half, or terminal portion, of a chromosome. In column 2, this half chromosome is indicated by the odd number of the numbered ends of the primary chromosomes. Complementary to this is the extra chromosome made up of the two even-numbered ends. (Col. 4.)

In mutations called tertiary the extra chromosome is made up of united end portions from two nonhomologous chromosomes. These are listed in column 5; each one twice.

Secondaries have been discovered for all except the smallest two chromosomes. For four chromosomes, both the primary and its two complementary secondaries are known. (Cols. 2 and 4). The tertiary chromosomes DS, Wy, and SE have been isolated from chromosomal races found in nature, such as the "B" race discussed in an earlier paragraph. They originated presumably through segmental interchange, as also probably the tertiary chromosomes Mp, ES, and X which were formed in cultures of our standard line 1. The other named tertiaries have been induced by radiation treatment. Of the tertiary chromosomes represented by figures in parentheses, the ends are known, but their effects upon the plant, when present as extras, have not been adequately studied. After a little practice the primary, secondary, and tertiary (2n+1) types are easily recognized without microscopic examination by the effects upon various parts of the plant brought about by the presence of the extra chromosomes or new combinations of fragments of chromosomes.

## DOUBLE (2n+1+1) TYPES

In addition to types with a single chromosome extra, combinations of these types in double (2n+1+1) forms are known. The simplest double type is a combination of two primaries. In Plate 11 is shown a capsule of the double type "Ilex-Globe" together with capsules of the (2n+1) types "Ilex" and "Globe", and of a normal (2n) for comparison. The adjoining diagrams show the chromosomes. In Ilex the smallest chromosome is extra. Among other effects, it reduces the size of the capsule and causes the spines to be slender. In Globe, the next to the smallest chromosome is extra. The extra Globe chromosome is responsible for a depressed capsule. In Ilex-Globe, in which both the Ilex and the Globe chromosomes are extra, the capsule has the globose shape due to the Globe chromosome and the fine spines and small size due to the Ilex chromosome. The characters of the capsule and other parts of the plant in double mutant types are the resultant of the interacting factors in the two extra chromosomes.

Double (2n+1+1) types are occasionally found occurring spontaneously. They are found in large numbers in the offspring of triploids (3n) along with the 12 primaries and normals (2n). Plate 12 shows capsules from primary and double chromosomal types which appeared among 1,152 offspring of triploids (3n) grown in 1925. The double types which were recognized at that time by other characters but which had no capsules suitable for the photograph are indicated by a +. Other double types which have been found in later cultures are indicated by a (+) in parentheses. The lower horizontal row contains capsules of 11 of the 12 primary (2n+1) types. The twelfth (Sp) is less common than the rest and was omitted from the photograph. Each double type may be considered a combination between two primary (2n+1) types, since it has two extra chromosomes in different sets corresponding to the extra chromosomes in the two respective primaries listed at the ends of the intersecting columns.

## COMPENSATING TYPES

In compensating types there may be only a single extra chromosome, so far as the counts show, but two modified chromosomes are actually present. The condition may be illustrated by the compensating type "Nubbin" (Nb). A capsule of Nb, together with capsules of the types which it throws in its offspring, is shown in Plate 13, Figure 1. Bk, Rl, and Ec are primary (2n+1) types and need not concern us here. Ph and Hg are tertiary (2n+1) types which have as their extra chromosomes the modified chromosomes present in Nb. The matter will be made clearer by the diagrams of the chromosomes of Nb shown in Figure 5. The Rolled (Rl) chromosome (1·2)

is our old friend the white chromosome. The chromosome 5·6 is "Buckling" (Bk) and 9·10 is "Echinus" (Ec). The chromosomes 5·6 and 9·10 are in pairs but there is only one normal 1·2 chromosome present. However, the "Pinched" (Ph) chromosome (5·2) furnishes the 2 half and the "Hedge" (Hg) chromosome (1·9) furnishes the 1 half of the missing 1·2 chromosome. The portions 1 and 2 in these two chromosomes are said to compensate to give the equivalent of a normal 1·2 chromosome. There is left over as extra chromosomal material, therefore, the 5 half and the 9 half chromosomes. The 5·2 and 1·9 chromosomes are tertiary chromosomes which, as extras in the types Ph and Hg, are thrown by the compensating type Nb. (Pl. 13, fig. 1.)

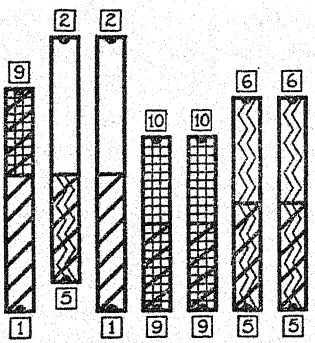



FIGURE 5.—Models of the chromosomes involved in the compensating type "Nubbin." The chromosomes 5·6 and 9·10 are in pairs but only a single 1·2 chromosome is present. However, the tertiary 5·2 chromosome furnishes the 2 half and the tertiary 1·9 chromosome furnishes the 1 half of the missing 1·2 chromosome. The 5 and 9 parts are left over as extra chromosomal material to bring about the peculiarities of Nb

The related chromosomes involved in Nb may be given by the following formula:

9·10—10·9—**9**·*1*—1·2—*2*·**5**—5·6—6·5.

The dashes indicate the connections of the chromosomes at the reduction divisions. The chromosomes of Nb, as of other compensating types with two tertiary chromosomes, form a chain of seven attached members. In this as in the following cases the parts which compensate are shown in italics and the parts which remain as extra chromosomal material are shown in boldface type.

MD is another compensating type with the same chromosome (1·2) compensated. Its formula is:

9·10—10·9—**9**·*1*—1·2—*2*·**17**—17·18—18·17.

MD shows some resemblance to Nb because of the 9 half chromosome which is in excess in both types. Its appearance, however, is affected more strongly by the excess 17 half and in consequence its resemblance to Nb is not great.

The formula of another compensating type which is not yet named is:

13·14—14·13—**13**·*11*—11·12—*12*·**17**—17·18—18·17.

In this case the 11·12 chromosome is compensated and the extra chromosomal material is 13 and 17. This type shows some resemblance to MD on account of the 17 half chromosome which is extra in both types. Because the remaining extra chromosomal material is not the same in the two types the two forms are not alike in appearance.

The three examples that have been given involve compensation between two tertiary chromosomes. A tertiary and a secondary chromosome may also compensate. An example is the compensating type involving the white and the stippled chromosomes. Models of the type are shown in Plate 13, Figure 2. Its formula is:

$$17\cdot\mathit{17}—17\cdot18—\mathit{18}\cdot1—1\cdot2—2\cdot1.$$

Compensating types involving a secondary and a tertiary chromosome form a chain of five attached chromosomes at reduction division.

Another compensating type, similar to the one just given but of different appearance, has the following formula:

$$3\cdot\mathit{3}—3\cdot4—\mathit{4}\cdot22—22\cdot21—21\cdot22.$$

In addition to compensations between two tertiary chromosomes and between a secondary and a tertiary chromosome, it should be possible to obtain compensations between a fragment and a tertiary, and between a fragment and a secondary chromosome. Such types have not yet been obtained but crosses have been made from which it will probably be possible to secure them.

With the examples given in mind, it will be possible to define a compensating type as one in which parts of two different composite chromosomes compensate to form the equivalent in chromosomal material of a whole normal chromosome, leaving the remaining non-compensating parts of the two composite chromosomes to bring about changes in structure in the plant affected.

## ORIGIN OF CHROMOSOMAL TYPES

Of the balanced types, the 1n or haploid comes from the development of an unfertilized egg cell and hence has the same reduced number of chromosomes as the sex cells. Haploids have arisen spontaneously over a hundred times in our cultures of the Jimson Weed, but what external stimulus if any is responsible for their occurrence is not known. Haploids have been found in several other species.

Tetraploids (4n) have been relatively abundant in Datura. They frequently appear first as a 4n branch on an otherwise 2n plant. This fact and other evidence leads to the belief that the doubling of chromosomes takes place after fertilization has occurred. High temperature at time of seed germination seems to stimulate the production of 4n individuals.

Triploids (3n), as earlier shown, are produced by crossing a 4n individual with pollen from a 2n plant.

Of the (2n+1) types, the primaries arise spontaneously from time to time in our cultures but can be obtained in great numbers among the offspring of 3n parents.

Secondary (2n+1) types occur spontaneously, but much less frequently than the primaries. There is no known method of obtaining them in large numbers.

Tertiary (2n+1) types have been obtained by a number of different methods. (*a*) A few have occurred spontaneously in our cultures. (*b*) They have been secured from cryptic chromosomal races in nature, such as the "B" races. (Fig. 4.) By crossing the "B" race, for example, onto a (2n+1) type in which the extra chromosome is related to the modified chromosomes of the "B" race, a (2n+1) tertiary may be secured in the next generation. By this method we have secured the tertiaries Wy (pl. 10, fig. 2) and DS. (pl. 10, fig. 1). (*c*) Since it is known that other species differ from our standard line 1 in the arrangement of the parts of their chromosomes more than does the "B" race, these other species probably afford another rich source of tertiary forms. Some success has already been had in seeking tertiary forms from this source. (*d*) The most prolific method of obtaining tertiary chromosomes, however, is treatment with radium or X rays. Under this stimulus, nonhomologous chromosomes are broken and their parts interchanged to produce tertiary chromosomes such as were described for the "B" race. (Fig. 4.) In hybrids between "B" race and our standard line 1 the chromosomes at the reduction division are seen to be connected together in a circle of four. (Fig. 6.) This configuration results because like ends of chromosomes are attached together at the reduction division. In a similar manner circles of attached chromosomes result when radiation has induced segmental interchange between two nonhomologous chromosomes. Thus following radiation treatment, the chromosomes 1·2 and 13·14 interchanged segments to form the tertiary chromosomes 1·14 and 2·13. The following circle resulted:

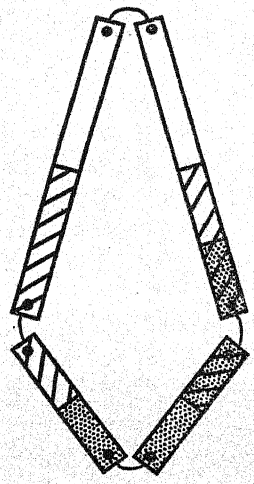


FIGURE 6.—Models of the circle of four attached chromosomes in hybrids between the standard line 1 and a "B" race. For chromosomal diagrams of the parental races see Figures 3 and 4

$$\begin{array}{ll} \mathbf{1\cdot 2} & \mathbf{2\cdot 13} \\ \mathbf{1\cdot 14} & 14\cdot 13 \end{array}$$

The tertiary chromosomes are represented in bold-face type. Another configuration following radiation was a circle of four as follows:

$$\begin{array}{ll} 13\cdot 14 & \mathbf{14\cdot 24} \\ \mathbf{13\cdot 23} & 23\cdot 24 \end{array}$$

By the proper breeding procedure these types, which are hybrid for the modified chromosomes and therefore show circles of four, may be purified so that the new tertiary chromosomes are in pairs. Such purified races with modified chromosomes are called *prime types.* By crossing such prime types onto the proper (2n+1) forms, it is possible to get the modified chromosome as an extra and thus to form (2n+1) tertiary forms. At the present time we have 40 different prime types and about 90 types with circles or chains which we are attempting to purify into prime types.

Translocations have been also induced by radiation. In a specific case the 1·2 chromosome was broken in two and the 2 half was translocated and permanently attached to the 11 end of the 11·12 chromosome making a large compound chromosome 2·11·12. The 1 portion was left free as a fragment. We have gotten rid of the 1 fragment and obtained plants with one and others with two of the 2·11·12 chromosome. The latter breed true and have given rise to a distinct race very different in appearance from normal 2n plants from which they arose.

Compensating types may be obtained in various ways such as by crossing a prime type onto the appropriate secondary (2n+1) form and obtaining the compensating type in the next generation. In the offspring of a plant with a circle of six attached chromosomes, one should expect from one to three compensating types according to the manner in which the abnormal chromosomes have been modified. Thus radiation treatment induced a circle of six with the following composition:

11·12—12·17—17·18
|  |
11·13—13·14—14·18

In the next generation a compensating type was obtained in which the 11·13 and the 12·17 tertiaries compensated for the 11·12 normal chromosome.

Circles of six and more chromosomes may be obtained as a source of compensating types by crossing two appropriate prime types together. Thus we have two prime types (*a*) and (*b*). The formula for (*a*) is: 1·14, 2·13, 23·24. The formula for (*b*) is 1·2, 13·23, 14·24. When either is crossed with our standard line 1, a circle of four results as shown in a preceding paragraph. When (*a*) is crossed with (*b*) the hybrid which results has a circle of six. The formula of this circle would be as follows:

1·2 — 2·13—13·23
|  |
1·14—14·24—24·23

By crossing prime types together we have obtained circles composed of as many as 10 chromosomes. The larger the number of chromo-

somes in a circle the greater the opportunity for the occurrence of compensating types in the offspring.

## SUMMARY OF CHROMOSOMAL TYPES IN DATURA

In the preceding section the manner of origin of the most important chromosomal types in the Jimson Weed has been discussed. In the present section a summary will be given of the types so far identified in this species.

In Table 2 (p. 450) the main chromosomal types are listed together with the number of different forms actually identified and the number theoretically possible for each type. The calculations are based on the assumption that the two parts into which a chromosome breaks are always equal. This assumption is known to be contrary to fact and in consequence the number of forms theoretically possible is much larger than the calculated figures. Formulae are given in the last column which enable one to apply the calculations to species with different numbers of chromosomes. Primary, secondary, and tertiary chromosomes are represented by the Roman numerals I, II, and III. It should be pointed out that these three kinds of extra chromosomes are defined in terms of our standard line 1. The class numbers in the column at the left may be of convenience for reference.

Of the unmodified balanced types, 1n, 2n, 3n, and 4n forms are the only ones so far obtained in Datura. Doubling of the 3n and of the 4n types should give 6n and 8n forms but these theoretically possible forms have not yet been found in Datura.

Class 5 are the primary (2n+1) types. Of these types, each with an unmodified chromosome extra, there can be only as many as there are different kinds of chromosomes. All the 12 possible to Datura have been identified.

Class 6 are the secondary (2n+2/2) types in which the extra chromosome consists of a doubled half chromosome. Since there are 24 halves that can be doubled, there are 24 secondary types that are theoretically possible. Of these, 14 have been identified and kept under cultivation. Two of the primaries (El and Sp) have very poor viability but each has a single secondary with good viability. Since a primary is intermediate in character between its two secondaries, it is likely that the missing secondaries of El and Sp would have too poor viability to permit them to survive even if they were actually formed. Others of the missing secondaries may also be nonviable. For convenience in explanation, we have spoken of the secondary chromosomes as having been formed by a doubling of one-half of a normal chromosome. There is evidence, however, that the parts into which a chromosome breaks in the formation of a secondary are not always equal.

Class 7 are the tertiary (2n+1) types formed by segmental interchange between nonhomologous chromosomes. Their ends therefore are from different primary chromosomes. Judging from interchanges involving three chromosomes, it appears probable that more than two chromosomes may take part in the formation of a tertiary chromosome. Moreover, the fact that the interchange in several cases is known not to involve exact halves of the two chromosomes involved is further evidence that the number of tertiaries theoretically possible is much larger than the 264 given in the table. A considerable number of chromosomes have been identified as tertiaries but the morphological characters of eight (2n+1) tertiary forms have been studied in cultivation.

Class 8 has two extra chromosomes but they are both in the same set. The (2n+2 Gl) shown in Plate 9 is an example.

Class 9 also has two extra chromosomes in the same set but one of these extras is a primary and the other a secondary.

Class 10 includes the double (2n+1+1) types which have two extra primary chromosomes in different sets. Examples have been given in Plates 11 and 12.

Class 11 comprises the double types which have extra chromosomes in different sets, one of the extras being a primary and the other an unrelated secondary chromosome.

Class 12 comprises the double types in which one of the extras is a primary and the other a tertiary chromosome.

Class 13 comprises the rare group in which there are three extra chromosomes, each in a different set. One form of this type has been surely identified by its chromosomes. It was too feeble in growth to give offspring.

Class 14 comprises types in which one chromosome has been dropped out. Such types would be expected only as abnormal branches on otherwise normal plants. A number of deficiencies of this kind have been found but so far as analyzed they have been caused by a dropping out of one of two chromosomes (Rl or Pn). Apparently a sex cell (1n) can not live unless all the 12 different chromosomes are present. Hence, deficiencies would not be expected directly from sexual reproduction.

Class 15 is similar to class 14 in that one branch is a chromosomal deficiency. In class 15, however, the plant begins as a secondary (2n+2/2) type and the chromosome that is eliminated is a primary related to the secondary chromosome. Thus a "Dwarf" type, which has a 17·17 chromosome in addition to two 17·18 chromosomes, lost one of the 17·18 chromosomes in forming an abnormal branch.

Class 16 includes the compensating types in which the compensation is between a secondary and a tertiary chromosome; while in class 17 the compensation is between the two tertiaries.

Class 18 is a compensating type like those in class 17 which, in addition to two tertiary chromosomes, contains an extra primary chromosome.

Class 19 includes types with a single fragment of a chromosome extra. By inbreeding, types may be obtained with two of some of these fragments. These are included in class 20. Similarly an attached (or translocated) fragment may be present once or twice to form the types represented by classes 21 and 22. A considerable number of primary and secondary (2n+1) types have been combined with the fragment types of class 19 and with the translocated type of class 21. These compound types are distinct but have not been included in the tabulations.

The modified diploids (2n) listed in classes 5 to 22 are the most distinct of the extra chromosomal types. As pointed out in the discussion of the different "Globe" types shown in Plate 9, the addition of an extra chromosome to a 3n or to a 4n type brings about relatively little change in the appearance of the plant affected. However, 4n types may be strongly modified by the addition of a larger number of chromosomes than would be possible in the diploid (2n) series. Furthermore, deficiencies may be transmitted by the sex cells of 4n parents since the normal sex cells of 4n plants are 2n. A (2n−1) sex cell would be a deficiency but might be viable since it would have at least one chromosome of each kind. The most extreme modification of a 4n is that given in type 32. In two different sets, Doctor Belling found an extra chromosome and in two other sets he found a single chromosome missing. The 3n and 4n types modified by deficiencies were determined by study of their chromosomes. The plants were obviously abnormal but the abnormalities have not been connected up with the particular chromosomes which were missing. It is difficult to evaluate the unbalance due to the addition or loss of single chromosomes in the 3n and 4n series.

By means of extra chromosomes and parts of chromosomes it has been found possible to secure a wide range of variations in Datura affecting the structure and physiology of all parts of the plant that have been studied. In fact, chromosomal variations in this species have been much more frequent than apparent changes in the ultimate factors or genes, as may be seen by comparing the genes listed in Table 1 with the chromosomal types in Tables 1 and 2.

It is not believed that Datura is an exception among plants in that it is capable of producing visible variations in large numbers by means of major changes in amount of chromosomal material.

Probably any other plant equally well adapted to breeding experiments would give similar results when sufficiently investigated. Evidence has been accumulating that select horticultural varieties, which have been kept true to type by vegetative propagation, are frequently characterized by extra chromosomes. Pending detailed analysis of such forms, it is logical to attribute their desirable characters as much to the extra chromosomes which they possess as to any individual factors in respect to which they may differ from the average.

Extra chromosomes in unbalanced types are transmitted to only part of the offspring. Such types, however, can be multiplied by cuttings, grafts, and other vegetative methods of reproduction. By such means horticulturists in the past have unwittingly propagated chromosomal types which were only later recognized as such when their chromosomes were studied. It is our belief that in the future extra chromosomes will be consciously utilized as a source of desirable variations in plants of economic importance.

TABLE 1.—*List of primaries, secondaries, and tertiaries arranged by size of chromosomes in the trisomic set*

[Ends of chromosomes are designated by numbers 1 to 24]

| 1<br>Chromosomes size class | 2<br>Secondary chromosomes and (2n+2/2) type | 3<br>Primary chromosomes and (2n+1) type | 4<br>Secondary chromosomes and (2n+2/2) type | 5<br>Tertiary chromosomes and (2n+1) type | 6<br>Genes located in particular chromosome |
|---|---|---|---|---|---|
| L | Py (1·1) | Rl (1·2) | Sg (2·2) | DS=2·17<br>Wy=1·18.<br>ES=2·9.<br>Ph=2·5.<br>Hg=1·9.<br>trSg=12·11·2. | p in Wy. |
| l | Sm (3·3) | Gs (3·4) | | Mp=4·6<br>(3·21).<br>(4·22). | fw, Bz in 4 half. QS in Gs, half not yet determined. |
| l | St (5·5) | Bk (5·6) | At (6·6) | Mp=4·6<br>Ph=2·5. | |
| M | Un (7·7) | El (7·8) | | | |
| M° | Mt (9·9) | Ec (9·10°) | Th (10°·10°) | SE=9·20°<br>(10·19).<br>ES=2·9.<br>Hg=1·9. | MS in either Ec or Sp. |
| M° | Wd (11·11) | Ck (11·12°) | | trSg=12·11·2<br>(11·21).<br>(12·22). | in, tf, e, sky, in 12 half. |
| M | Not named (13·13). | Mc (13·14) | Not named (14·14) | X=18·13 | al. |
| M | Sc (15·15) | Rd (15·16) | | | tc in 16 half. |
| m | Df (17·17) | Pn (17·18) | | DS=2·17<br>Wy=1·18.<br>X=18·13. | c, wt in 17 half; p in 18 half. |
| m° | Dv (19·19) | Sp (19·20°) | | SE=9·20°<br>(10·19).<br>trIx=(20·19·23) | sh. MS in either Sp or Ec. |
| S° | | Gl (21°·22) | | (3·21)<br>(4·22).<br>(11·21).<br>(12·22). | sc, bb, pl. |
| | | Ix (23·24) | | trIx=(20·19·23) | sw. |

The ends 10°, 12°, 20°, and 21° are characterized by terminal humps.

TABLE 2.—*Chromosomal types in Datura Stramonium*

[The number of forms actually identified and the number theoretically possible are shown for each type. Calculations are based on the assumption that the two parts into which a chromosome breaks are always equal. Since this is known not to be the case, the figures given form a minimum. The Roman Figure I indicates an unmodified or primary chromosome; II a secondary chromosome (with two like ends); III a tertiary chromosome (with ends from two different primaries)]

| Class No. | Chromosomal types | Number of forms identified | Number of forms theoretically possible | Formulae |
|---|---|---|---|---|
| 1–4 | 1n, 2n, 3n, 4n | 4 | 4 | |
| 5 | 2n+I | 12 | 12 | n. |
| 6 | 2n+II | 14 | 24 | 2n. |
| 7 | 2n+III | 8 | 264 | 2n (n−1). |
| 8 | 2n+2 I | 2 | 12 | n. |
| 9 | 2n+2 (I and II) | 1 | 24 | 2n (I and II related) |
| 10 | 2n+I+I | 47 | 66 | $\frac{n\,(n-1)}{2}$. |
| 11 | 2n+I+II | 9 | 264 | 2n (n−1) (I and II unrelated). |
| 12 | 2n+I+III | 2 | 3,168 | $2n^2\,(n-1)$. |
| 13 | 2n+I+I+I | 1 | 220 | $\frac{n\,(n-1)\,(n-2)}{6}$ |
| 14 | 2n−I | 2 | 12 | n. |
| 15 | 2n+II−I | 1 | 24 | 2n (I and II related). |
| 16 | 2n−I+II+III | 4 | [1] 264 | 2n (n−1). |
| 17 | 2n−I+III+III | 3 | [1] 264 | 2n (n−1). |
| 18 | 2n−I+III+III+I | 2 | 3,168 | 2n [2] (n−1). |
| 19 | 2n+1 free fragment | 7 | 24 | 2n. |
| 20 | 2n+2 free fragments | 4 | 24 | 2n. |
| 21 | 2n+1 translocated fragment | 1 | [2] 24 | 2n. |
| 22 | 2n+2 translocated fragments | 1 | [2] 24 | 2n. |
| 23 | 3n+I | 1 | 12 | n. |
| 24 | 3n−I | 1 | 12 | n. |
| 25 | 4n+I | 8 | 12 | n. |
| 26 | 4n+2 I | 1 | 12 | n. |
| 27 | 4n+3 I | 1 | 12 | n. |
| 28 | 4n−I | 5 | 12 | n. |
| 29 | 4n+I+I | 1 | 66 | $\frac{n\,(n-1)}{2}$. |
| 30 | 4n+I−I | 1 | 132 | n (n−1), |
| 31 | 4n−I−I | 1 | 66 | $\frac{n\,(n-1)}{2}$. |
| 32 | 4n+I+I−I−I | 1 | 2,970 | $\frac{n(\ -1)\,(n\qquad 3)}{4}$ |

[1] 264 morphological types, but 528 different chromosomal types, if the parts of chromosomes which have interchanged are considered.

[2] 24 morphological types, but 576 different chromosomal types if ends to which fragments are translocated are considered.

# THE AGE OF THE HUMAN RACE IN THE LIGHT OF GEOLOGY[1]

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[With 3 plates]

There is perhaps no problem upon which we find more divergence of opinion than upon this one of the age of the human race. Between those who still adhere to an age of 6,000 or 8,000 years, as was assumed by the older Biblical exegesis, and those who are exceedingly liberal even with millions, we find all possible shades of opinion. Thus it is impossible for a nonspecialist to find his way through this tohu vabohu and to form a clear judgment. In consequence many have only ridicule for all endeavors to give even approximate figures. The disagreement even amongst the greatest authorities seems to them to show that we can accomplish nothing toward the solution of this problem. However, the situation is not so bad as that, and although there are many uncertainties which prevent the determination of exact figures and which are the cause of the discrepancies among scientists, at least a minimum age can be assigned to mankind. In the following pages an attempt has been made to derive such a minimum from the geologic facts and to show that the age of mankind can not be less than a certain number of millenniums, although it may of course be higher.

## MAN IN THE GEOLOGIC TIME SCALE

It is impossible to express the age of mankind in the usual measure of years, unless we know the position of man in the geologic time scale; that is, the relative age of the human race must be found out in terms familiar to geologists. In what geologic period did man arrive on earth? To be more exact: In what geologic period do we find the first unmistakable indications of man's presence?

It is, first, an established fact that man was witness of the glaciation in northern and central Europe. His tools and weapons and his

[1] Reprinted by permission, with author's revision, from publications of the Catholic Anthropological Conference, vol. 1, No. 2, March, 1929.

skeletal remains are found in association with the remains of animals and plants of this cold epoch, in such a way as to demonstrate that man was a contemporary of these animals and plants, as, e. g., the woolly mammoth, the woolly rhinoceros, the reindeer as far south as northern Spain. Man utilized the ivory of the mammoth and the antlers of the reindeer for the manufacture of his implements. He painted these animals on the walls of his caves and engraved them on his tools. Plants of the arctic tundra are found in the deposits of the habitations of man, and shells of clams belonging to the arctic zone—*Pecten islandicus* and *Cyprina islandica*—show that the ocean and the fresh water basins were cooled down to arctic temperature, even on the northern coast of Spain. Almost innumerable finds illustrate these facts and they have been studied with painstaking care by a number of specialists all over Europe.

Secondly, there is unanimous agreement that man was in Europe even before the last period of severe cold. In the Somme Valley, France, primitive stone implements of man occur in association with animals quite different from those mentioned above. The arctic forms are wanting—no reindeer, no mammoth, no animals of the tundra. A southern elephant was living there instead of the mammoth, and the hippopotamus, an animal which can not live in waters that freeze over, was found in the rivers of France and England. In the same rivers a bivalve, *Corbicula fluminalis*, was common which is now limited to Asia and Africa. All these facts exclude a glacial climate at this period. Moreover, from the Seine Valley calcareous tufas have been described, containing plants which require an average temperature 4° to 5° higher than is the temperature to-day at the same place. Prehistorians designate this stage of human culture as Chellean. Now, the following Acheulian stage, whose implements of a finer make rest immediately upon those of the Chellean, contains plant remains of a colder climate and the bones of mammoth and reindeer, thus demonstrating that the cold with a new glaciation was approaching.

Hence it is proven beyond any reasonable doubt that man was in Europe during a rather genial climate preceding the last glaciation, and that he witnessed this process of glaciation from its beginning to the complete disappearance of the ice. This conclusion is not based on a few stone implements, nor on a few bones of man found somewhere. It has been reached by the conscientious study of numerous prehistoric stations of man throughout central and southern Europe. These studies were carried out by well-trained scientists, amongst whom a number of Catholic priests, such as Prof. Hugo Obermaier, the Abbé Henri Breuil, the Abbés A. and J. Bouyssonie, Prof. F. Birkner, are leading authorities. Owing to these researches a great number of skeletal remains of man of the glacial period have been

unearthed. Man of the Neanderthal race, living in the first portion of the Old Stone Age, in the cultural stages of the Acheulian and Mousterian, is represented at least by 11 skeletons, of which 7 are in good preservation, and by fragmental remains of 19 individuals. Neanderthal man was succeeded by quite a different human race which lived in the last part of the Old Stone Age and the glacial period. Fifty-two skeletons of this race are extant and portions of other skeletons representing about 30 individuals.

## AN ABSOLUTE CHRONOLOGY FOR LATE GLACIAL AND POSTGLACIAL TIME

Are there reliable methods for dating back these geologic events and for expressing in millenniums the time elapsed since their occurrence? Many attempts have been made in the past to determine this time. Most of them did not go beyond rough estimates, leaving much to subjective feeling and fancy. The cutting of the Niagara gorge below the falls is supposed to furnish a good measure of the time elapsed since the recession of the ice, for these falls could not begin their work before the ice sheet covering North America beyond New York City retreated to a place north of the present falls. But there are so many uncertainties in the determination of this time that the figures given differ all the way from 7,000 to 39,000 years. Besides, the connection of this event with the appearance of man in Europe is still very problematical. Even more open to exception are calculations based on the thickness of deposits left in lakes after the recession of the ice.

The study of such deposits in lakes, however, was developed by Prof. Gerard Baron de Geer, of Stockholm, into a new method which is recognized as the best and most reliable one for measuring the millenniums since the definite recession of the ice from a given locality. Professor de Geer reported on this method and its results to the Eleventh International Geologic Congress sitting in Stockholm in 1910.[2] Since then it has been applied to numerous localities both in Europe and in America by De Geer and his students and coworkers, and it has found unreserved approval and acceptance from geologists.

To illustrate De Geer's procedure we may take an example of a recent glacier. The melting waters of the Victoria Glacier in the Canadian Rockies (Alberta), after a course of about 1 mile, are poured into Lake Louise, a mountain lake 1¼ miles long and one-half to three-eighths mile wide and 5,760 feet above sea level. During the summer months the melting waters of the glacier are turbid and milky from the detritus carried away from the melting ice. In the lake

[2] A geochronology of the last 12,000 years, Congrès géol. intern. XI. Compte rendu, Stockholm, 1912, p. 241 ss.

the coarser material soon settles, while the finer clay remains suspended and falls down very slowly in late fall or winter, when Lake Louise is frozen all over with an ice cover about 40 inches thick. The deposits at the lake bottom are, therefore, found to consist of coarse layers of silt and sand alternating with fine layers of clay; the coarse sediments being laid down during the melting period, the fine clays during the winter when there is no, or else very little, melting of the glacier. There is also a difference in the color of these two layers, the winter layer being, as a rule, of a darker hue.[3]

The same conditions as observed at present in Lake Louise occurred very frequently during the melting of the enormous ice sheets which covered the northern part of Europe and North America during the glacial period. At many places the drainage of a district was blocked by the deposits made by the melting ice sheet, when the front of this ice sheet stood for a considerable time at the same spot. As a consequence when the ice front later receded the dammed-up melting waters gathered in lakes, forming coarse layers in summer and finer and darker ones in late fall and winter, thus giving origin to banded clays. One pair of these bands (or varves, after the Swedish word) forms in one year, just as an annual growth ring in trees forms during one year. (Pl. 1.)

Such " varved " clays occur on a large scale in southern and central Sweden, where the rivers of the late glacial ice sheets, carrying the detritus of the ice, poured their water into such lakes. Here De Geer began his studies and counted with his students the varves from the Scania Peninsula in southern Sweden to Jämtland in central Sweden, over a distance of 800 kms. (500 miles). He found 5,000 pairs of layers requiring 5,000 years for their formation. Thus the retreat of the ice front from Scania to central Sweden occupied 5,000 years. This retreat was accomplished slowly in Scania, about 75 m. (250 feet) a year; farther north it increased to 100 m. (328 feet). Later, the melting set in rapidly and the yearly recession was from 100 to 300 m. (328 to almost 1,000 feet).

At the end of these 5,000 years the shrinking ice was bisected and retreated into the Scandinavian mountains. That was the end of the glacial period and the beginning of postglacial conditions. The duration of postglacial time was in a similar way determined by counting the varves laid down in the postglacial lake Ragunda and in the former fjord of Ångermanälven. The result was about 8,700 years with an uncertainty of 100 to 200 years; i. e., postglacial time lasted 8,500 to 8,700 years from its beginning until 1900 A. D. Therefore, southern Scania was freed from ice 8,700+5,000=13,700 years, or, using the lower figure, at least 13,500 years before 1900 A. D. (In

[3] W. A. Johnson, Sedimentation in Lake Louise, Alberta, Canada, Amer. Journ. Sci., 5th series, vol. 4 (1922), p. 376 ss.

the publication cited above[4] De Geer had calculated 12,000 years, based on studies in Ragunda Lake; these studies were regarded as preliminary only; the higher figure is based on more exact work of a later date.)[5]

De Geer's method was readily accepted and approved on the part of geologists, even when he first reported it to an international audience and showed characteristic varved clays in Sweden to the members of the Geologic Congress. Since then this approval has become universal amongst geologists and prehistorians. On the occasion of the Twelfth International Geologic Congress at Toronto in 1913, the Canadian authority on glacial geology, A. P. Coleman, said: "Probably the most accurate chronology is that worked out skillfully and patiently by Baron de Geer and his assistants."[6] The French paleontologist Boule calls De Geer's method "la plus ingénieuse et la plus suffisante."[7] Prof. James W. Goldthwait, of Dartmouth College, writes in his introduction to Antevs's publication reporting on the application of De Geer's method to America: "An investigation so precise in method and execution and so suggestive will give fresh impulse to our studies of Pleistocene glaciation."[8] Robert W. Sayles, geologist of the Harvard University Museum, after a careful examination of all the factors which might influence the deposition of the clays in question, reaches the conclusion: "I feel convinced that the seasonal theory is in a very strong position and that the danger of its being abandoned is very slight."[9] The late Prof. Eduard Brückner, of Vienna University, one of the leading authorities on the glacial geology of the Alps, accepts unreservedly De Geer's method.[10]

Indeed, all modern geologists take it for granted that the chronology based on clay varves is reliable. There exists no serious adverse criticism of the method. Absolute chronologies based on clay deposits were regarded with skepticism and mistrust, as long as the thickness of the deposits was taken as the measure of time. Climatic conditions are so variable and their influence on the amount of clay carried along by rivers is so unaccountable that they can never afford precise measurement. This disturbing factor does not enter into the new method. Variations in temperature and precipitation certainly influence the thickness of the clay layers, but these

[4] Cf. note 1.

[5] R. Lidén, Om isavsmältningen och den postglaciala landhöjningen i Ångermanland, Geol. Fören. Förhandl., Stockholm, 1911, vol. 33, pp. 271–280; G. de Geer, On the solar curve, as dating the Ice Age, the New York Moraine and Niagara Falls through the Swedish time scale, Geografiska annaler, 1926, vol. 8, pp. 274–284.

[6] Congrès géol. intern. XII., Compte rendu, Toronto, 1913, p. 435.

[7] Marcelin Boule, Les hommes fossiles, Paris, 1921, p. 60.

[8] Ernst Antevs, The recession of the last ice sheet in New England, Amer. Geogr. Soc., Research series no. 11, New York, 1921, p. IX.

[9] Museum of Comp. Zoology, Memoirs, Cambridge, Mass., 1919, vol. 47, p. 61.

[10] Zeitschrift für Gletscherkunde, 1921, Bd. XII, p. 55.

variations are no longer unknown quantities; they are plainly legible in the varves themselves. In a year with a warm summer the coarse portion of the varve will be thick; in a colder year the varves may shrink to small lamellae. Exceptionally rainy seasons and periods of excessive heat and drought will undoubtedly modify the depositions in lakes at the ice front. But such irregularities can always be distinguished from the seasonal varves if the latter are studied with due care over large areas.

De Geer's method has also been applied to varved clays in North America during the last decade. Antevs started this work in the Connecticut Valley. Varves were counted from Hartford, Conn., to northern Vermont, over a distance of 185 miles. Later, a number of varved clay deposits were studied in Canada, in Wisconsin and Minnesota, and recently by Chester A. Reeds in New Jersey and in the Hudson Valley, New York.

The researches have even been extended to Argentina in the Southern Hemisphere and to the Himalaya region. It has not been possible in these cases to construct a continuous time scale as in Scandinavia. But the method itself has been firmly established and has stood the test by many independent workers in widely separated areas.

## EXTENSION OF THE CHRONOLOGY BACKWARDS

The duration of late glacial and postglacial time in Scandinavia has been firmly established by De Geer and his colleagues. In round numbers, 13,500 years have passed since central Scania was freed from ice. How can this fact be used toward solving the problem of the age of the human race? This age is certainly higher than the above figure. In the first place, it must be taken into account that the ice border halted a considerable time before it melted away, forming moraines—that is to say, long stretched hills—composed of the detritus brought by the ice. Recently the duration of this stoppage, just before its final recession, has been determined by studying varved clays laid down by the melting waters of the ice in lakes of southwestern Scania and in the Danish islands Sjelland and Fyen. (See De Geer, citation 4 above.) This halt of the ice lasted almost 2,000 years, which, therefore, must be added to the above figure 13,500.

Furthermore, it is well known that the ice before this time covered the northernmost part of Germany, halting there again for a considerable time, as is seen from the formation of the very extensive elevations, the moraines of the Baltic Ridge, in which lakes and lakelets are abundantly developed, as in the moraines of Wisconsin and Minnesota. The duration of this stoppage and the time required for the retreat from northern Germany to southern Scania have not yet

been determined by exact methods. The latter can only be estimated from the rate of recession found in Sweden, while the duration of the stoppage must be derived approximately from the moraines deposited by the ice during the halt or the oscillations of its border. De Geer assumes 2,500 years; adding these to 13,500+2,000 found before, his final figure is 18,000 years; that is to say, 18,000 years ago the German Provinces of East and West Prussia, Pomerania, Mecklenburg-Strehlitz, and the eastern part of Schleswig-Holstein were still covered with mighty ice sheets. (Fig. 1.)

At a still earlier period the ice sheet reached farther south into the southern part of the Province of Brandenburg and south of Poznan in Poland. No data are at hand to determine the recession of the ice from this area until it reached the Baltic Ridge. An estimate of 1,000 years would, however, be in fair agreement with the observations made farther north. Thus, in all, the ice began its retreat from northern Germany about 19,000 years ago. It must be borne in mind that of this figure a little more than 15,000 years are the result of precise measurement. The remainder is a conservative estimate. It might well be that the ice stood a considerably longer time in northern Germany, its border alternately receding and readvancing. Thus Ernst Antevs arrives at essentially higher figures in his recent publication: "In all, the uncovering of the belt between the Great Baltic, or the Pomeranian moraine, and northeastern Scania must have taken many thousand years, probably 10,000 to 15,000."[11] Evidently such assumptions can not be definite, because they are not based on the counting of clay varves. Therefore the lower figures are here preferred, in order to avoid all statements which can not be proven, although the higher figures may be true or may approach the truth.

It will be recalled that man during this last glaciation was in Europe, struggling with the cold in southern France and northern Spain, and as companion of the arctic animals and plants. Furthermore, it was shown that man was in Europe before this severe cold arrived, since he was living with animals and plants requiring a much warmer climate not only in southern countries but as far north as Weimar in Germany. It is, of course, impossible to reconcile such a mild climate in central Europe with a glaciation and a large ice sheet in northern Germany. We must, therefore, conclude that at that period northern Europe was as much free from ice as it it at present, or even more so, if the indications of a higher temperature than to-day are reliable. With a new deterioration of the climate, then, the ice again took possession of central Europe, moving slowly from Scandinavia to central Germany.

[11] Ernst Antevs, The last glaciation, Amer. Geogr. Soc., Research series No. 17, New York, 1928, p. 160.

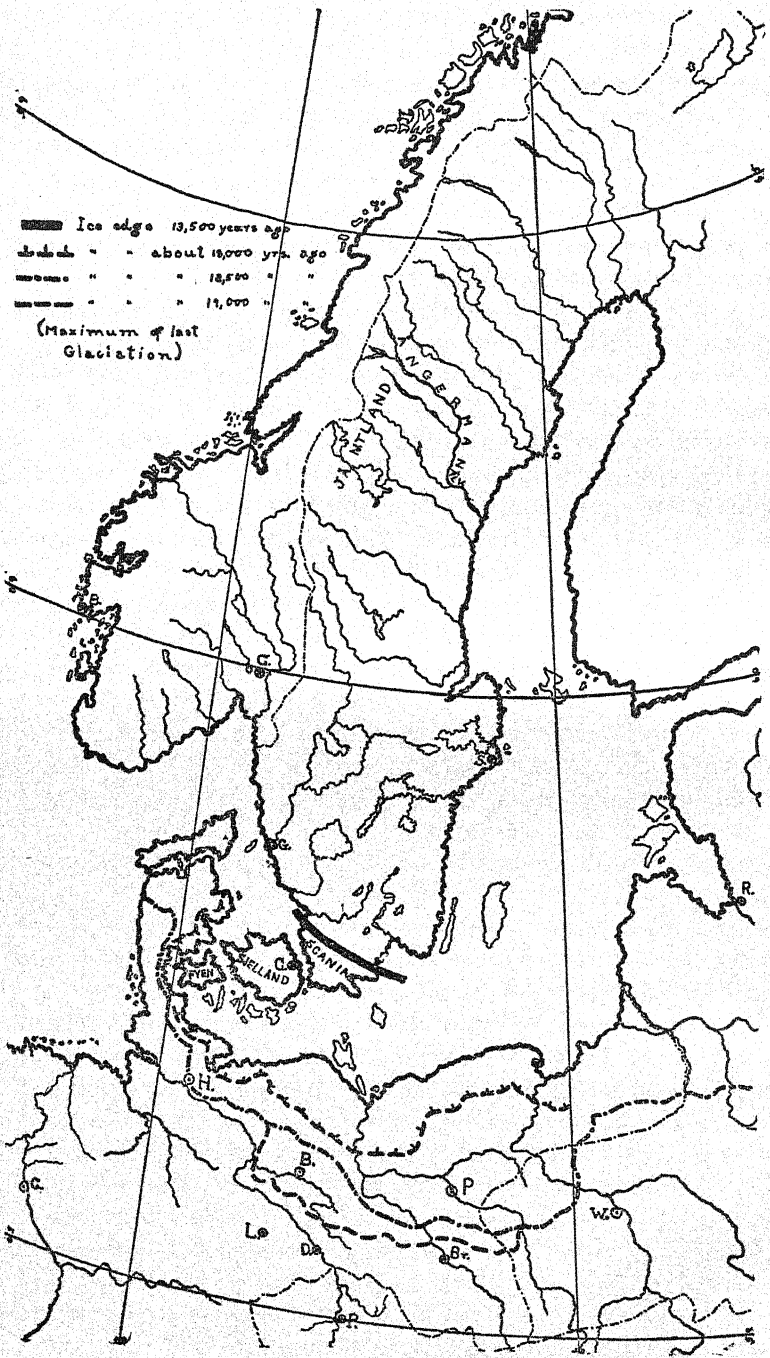



FIGURE 1.—The extension and recession of the last ice sheet in northern Europe

When this last glaciation was at its maximum, man was already living in central and southern Europe.

THE DURATION OF THE ADVANCE OF THE ICE

To determine the time needed for such a readvance no exact methods are at hand. We meet here with many uncertainties and unknown quantities which prevent an exact measurement. Moreover, we do not know how long the ice front stopped at the greatest extension of the inland ice, and how long man was in Europe before the ice started its readvance. Only an estimate of the readvance of the ice will be attempted in the following paragraphs.

The average motion of recent glaciers and ice fields is fairly well known. The Alpine glaciers move at a daily rate of 12 to 20 inches. There are examples of more rapid motion; this happens where a glacier is pushed with high pressure into a narrow valley or where the ice slides over a steep slope. Such conditions are, for example, responsible for the exceptional velocities of glaciers at the western edge of the large ice sheet of Greenland, where daily motions of 33 to 66 or even of 105 feet are recorded. It would be wrong to attribute such a speed to the whole body of the inland ice. The late Prof. Thomas C. Chamberlin long ago warned against such a procedure: "There is a widespread misapprehension as to the average rate of movement of the ice fields of Greenland. * * * In certain fiords, that lead out from great basins into which broad fields discharge their ice and their surface waters, and thus furnish the conditions for an extraordinary rate of movement, the rate of motion, at least during the summer, is unusually high, and these exceptional cases have been taken as representative of the movement of the border of the inland ice. This is very far from being true. The average movement for the whole border of the ice field is quite certainly less than 1 foot per day, and it is more likely less than 1 foot per week."[12] Others speak of a forward motion of only a few meters annually. If it were more, the ice would soon cover those parts of Greenland which for centuries have been free from ice, the wastage of the ice being exceedingly small on account of the short melting season.

The Pleistocene ice sheets were of enormous thickness, and they advanced, as a rule, over a flat country, spreading out over a very large area. The surface slope, which is of the greatest importance for the rate of movement, has been found to be very slight, as far as can be ascertained. All this points to a slow motion of the clumsy ice masses, although an exact rate can not be given. The southernmost portions of the ice may have moved faster than the Greenland ice because, reaching into an area of milder climate, the greater part of the ice was not far from its melting point. Conse-

[12] T. C. Chamberlain and R. D. Salisbury, Geology, 2d ed., 1907, Vol. III, p. 430.

quently, the flow of the ice became easier and the rate of movement increased, as is observed in Alpine glaciers far below the snow line. Even under these conditions a motion of 1 foot per day must be considered as high. However, assuming such a rate, it would take about 11,000 years for the ice to travel the distance of 750 miles from its origin in Scandinavia to northern Germany.

This figure gives an idea of the length of time required for an ice sheet to move over great distances. It does not, however, give a measure of the advance of the ice border. It is well known that the ice in moving forward melts. The amount of melting is in some cases so considerable that the ice front recedes, although the ice as a whole pushes steadily forward. Thus the front or tongue of the majority of the Alpine glaciers is retreating. The melting process was undoubtedly also active in Pleistocene time; during the advance of the ice its edge was melting. This wastage may have been small, compared with the motion of the ice, especially when the cold was at its climax; it may have been considerable when the climate was as yet less severe. In any case, on account of this melting, the above figure must be increased by an uncertain amount. To simplify the problem, this factor may be neglected, bearing always in mind that the figure is rather below the real value than above it.

As the final result of the preceding deductions it can be stated: Thirty thousand years ago man was certainly in Europe, living in a rather warm period preceding the last glaciation. This figure seems to be well established, and no scientist will raise serious objection to it so long as it is regarded as a minimum.

## WHY DO GEOLOGISTS ASSIGN A STILL HIGHER AGE TO MANKIND?

However, the great majority of geologists and prehistorians assume considerably higher figures for the age of the human race. Some reasons for such an assumption have already been alluded to. The rate of movement of the advancing ice seems in all probability to have been less than that assumed in the present paper, and therefore the time of advance longer. Moreover, the melting of the ice during its advance was neglected. Furthermore, how long was man living in a genial climate before the temperature dropped to such a level that the ice started its advance to the south? There are good geological reasons for concluding that the interglacial period preceding the last glaciation lasted much longer than the postglacial period, which latter had a duration of at least 18,000 years for northern Germany. (Pl. 3.) If man was already in Europe at the beginning of the last interglacial, then many thousands of years must be added to the above figure.

Finally, we have to take into account another possibility. The cradle of mankind was hardly in Europe. Even from the purely

scientific viewpoint one has to look elsewhere for man's birthplace. The question then arises: How long did man live in his place of origin before he migrated into Europe? And even in Europe man may have appeared much earlier than during the last interglacial period. For his presence during this period we have conclusive proofs confirmed by numerous observations and by the unanimous agreement of scientists. There are, however, strong indications that man was in Europe in the second last interglacial period. The human jawbone found at Mauer near Heidelberg in association with mammals of a more ancient type is ascribed by Dr. Hugo Obermaier to this second last interglacial. Likewise, some prehistoric sites containing stone implements together with the same ancient animals (Abbeville, France) are placed in the same period, the pre-Chellean, by Father Obermaier.[13] Many other geologists place even the Chellean in this second last interglacial period. If these views be correct, the age of mankind would exceed the above figure by many millenniums, because another recession and another advance of the ice must be added and also the unknown duration of the second last interglacial period.

Even so, the possibilities are not yet exhausted. The problem of Tertiary man has been very warmly discussed ever since the Abbé Bourgeois first advanced such a thesis in 1863. As skeletal remains of man are to date lacking in deposits of this period, the whole discussion has centered around flints of peculiar shape, the eoliths. According to some, these indicate manufacture by an intelligent being, while others consider them the products of mere natural processes. The best experts in paleolithic industry rejected the hypothesis of the human origin of eoliths, and thus the problem of Tertiary man seemed to be settled in the negative. However, about a decade ago flints were found in East England, near Ipswich, Suffolk, which revived the old controversy. These flints, evidently of great age, are considered by the great majority of experts as genuine human implements, although some specialists still reserve judgment. These implements are found in two horizons: At the base of the red crag and in its upper portion. The red crag is a marine deposit of the upper Pliocene (end of Tertiary time). The shells occurring in this crag, especially in its upper part, are partly arctic, announcing the approach of the glacial period. The Abbé H. Breuil, one of the ablest and most critical students of paleolithic stone implements, regards the flints found in the upper horizon of the red crag as intentionally made by an intelligent being. Of a number of the peculiar flints occurring at the base of the red crag, he says it is "absolutely impossible to distinguish them from the classical implements" (that is, im-

[13] See: M. Ebert, Reallexikon der Vorgeschichte, Vol. X, pp. 241 and 242, "Préchelléen," by Obermaier.

plements of later periods which are universally recognized as made by man). "The traces of fire are undeniable, whatever may be their origin."[14] L. Capitan, another expert, is even stronger in his verdict on certain implements of the same place: "If one would deny the genuineness of this piece, he must reject the greatest part of scrapers of the Mousterian. * * * These are flints purposely shaped by a rather skillful hand."[15]

Those who accept the opinion of these specialists date man as far back as the end of Tertiary time, or, what is more to the point, the beginning of the glacial period, when the inland ice was for the first time advancing toward central Europe. No wonder that they figure upon a very high age for the human race. If man was witness of three or four advances of the ice, if he was existing during two or three interglacial periods each of them of much longer duration than postglacial time, figures as high as several hundred thousands of years do not surprise us.

The time has not yet come to decide definitely for or against such assumptions. Until the skeletal remains of assumed preglacial man are discovered, some doubt is possible. It may also be, as Obermaier suggests, that the red crag, in which the supposed implements occur, belongs to the first glaciation in England (cold climate). If this be the case, man living during this period was not Tertiary man, although he must have appeared very soon after the close of the Tertiary.

In recent years a number of skeletal remains of a primitive man have been unearthed in China. Geological and paleontological evidence seems to point to a very high age of this man. Father Teilhard de Chardin, S. J., geologist of the Tientsin University, gives a succinct report of the discovery in a recent issue of "Primitive man."[16] According to him Sinanthropus Pekinensis belongs to the Lower Quaternary, while Neanderthal man was living in the Middle Quaternary. That would raise the figures for the absolute age of mankind considerably.

Up to the present the exceedingly high figures for the age of mankind have been derived from those theories which take it for granted that Europe was repeatedly glaciated, either three or four times. There are still geologists who do not accept long interglacial periods. They assume that the ice never entirely left the glaciated area during the whole Ice Age. The interglacial periods of others are to them only minor oscillations of the ice front. An advocate of such an opinion was Nils O. Holst, a Swedish geolo-

[14] Revue anthropologique, vol. 32, 1922, p. 228.
[15] Ibidem, p. 131.
[16] Teilhard de Chardin, Sinanthropus Pekinensis, Primitive Man (Publication of the Catholic Anthropological Conference, Washington), Vol. III, 1930, pp. 46–48.

gist, who estimated the duration of the entire Ice Age as 17,000 years and who ascribed to mankind an age of 30,000 years. There are still a few such monoglacialists left, but their number is fast dwindling away. Indeed, it is very difficult to invalidate the weighty evidence for repeated advances and recessions of the ice sheets. A warm climate, as is known from deposits lying between those of two glaciations, is certainly not reconcilable with big ice masses at no great distance. If, for instance, in what are evidently interglacial beds near Toronto, Canada, remains are found of such plants as grow at present in southern Pennsylvania, or if close to Hudson Bay in similar deposits tree trunks occur of 18 inches thickness, the climate must have been at that time even milder than to-day and the country must have been free of ice far to the north.

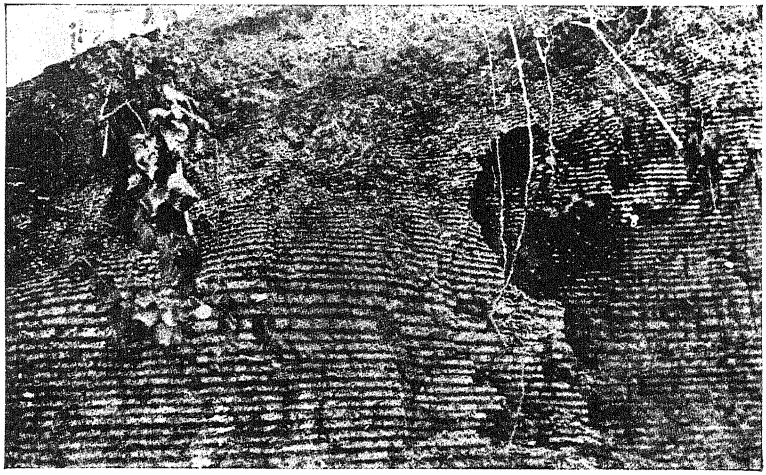
However, it is still disputed how many times such changes took place. The number of glaciations usually is given as three in northern Europe and as four in the Alps. The overwhelming majority of geologists agree that the assumption of at least two independent glaciations with a long warmer interval is imperative. Recently an anthropologist of Vienna, J. Bayer, drops the first glaciation in the Alps as unproven, and contracts the last and second last glaciation into a single one, only separated by a minor oscillation of the ice front. Thus two large glacial periods remain with one interglacial period of long duration, in which latter man was present.[17] Accordingly, the duration of the entire Ice Age is considerably diminished, although even Bayer speaks of about 200,000 years. On account, however, of the strong opposition of experts, this chronology can not be taken as a standard.

## CONCLUSION

It is evident from what has been said that there are many uncertainties which block any attempt to assign a definite figure for the age of mankind. On the other hand, it would be unreasonable and unscientific to reject all figures as uncertain and unreliable. There are facts which are obvious and which are accepted unanimously by all geologists, and these facts warrant the conclusion that man was undoubtedly in Europe 30,000 years ago. Of this number of millenniums the first half is determined by exact methods, as set forth in this paper; the other half is based partly on an estimate of the recession of the ice where this recession can not yet be measured directly, partly on a very conservative estimate of the time required for the advance of the ice front from northern to central Europe. Future development of these methods as well as new discoveries may raise this minimum figure considerably and may place on a more solid

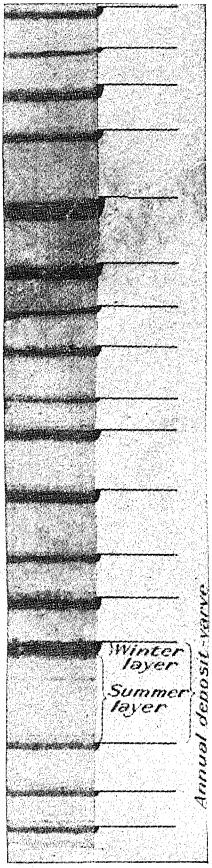
[17] J. Bayer, Der Mensch im Eiszeitalter, Wien, 1927.

basis the theories of those who stand for a much higher age of mankind. However, it seems impossible that the figure of 30,000 years will ever turn out to be too high as a reasonable estimate of the minimum age of the human race. In any case, the present essay clearly points out that it is impossible to reconcile the well-known facts of human antiquity with such figures as 6,000 to 8,000 years. No theological problem is involved, it may be added in conclusion. Theologians, even the more conservative, acknowledge full liberty to deviate from the figures of the older exegesis and declare that the problem of the age of mankind is, like that of the age of the earth and of the universe, one which has to be solved by secular science.



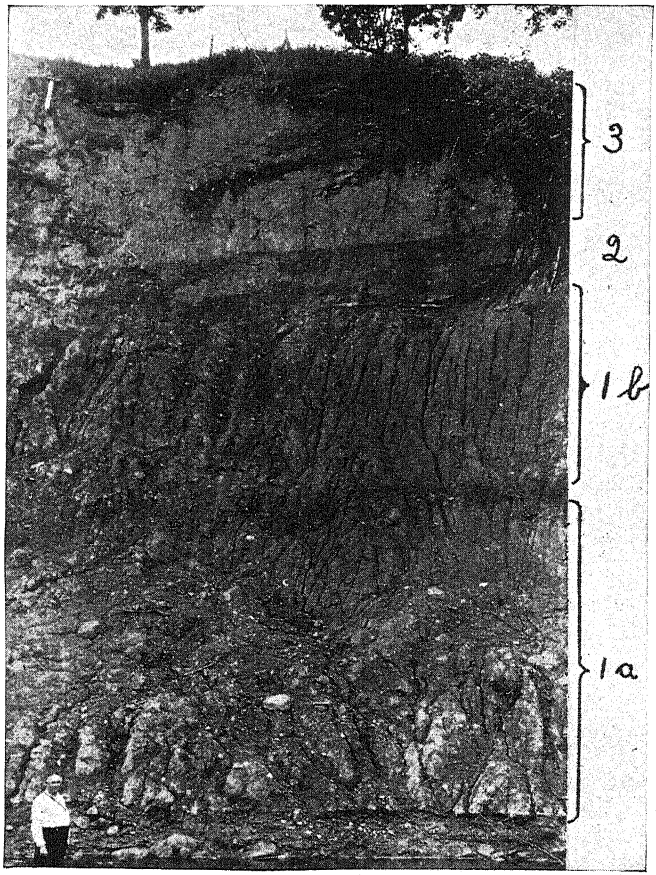
VARVED GLACIAL CLAY, SANDY FALLS, 6 MILES WEST-NORTHWEST OF TIMMINS, ONTARIO

From Memoir 146, Canada Geological Survey, Plate II, A. Ernst Antevs, Retreat of the last ice sheet in Eastern Canada. (Reproduced by courtesy of Geological Survey of Canada.)




VARVED GLACIAL CLAY FROM UPPER PART OF SECTION AT ESPANOLA, ONTARIO

Actual length 18 inches, laid down in 17 years. (Ibid., Pl. I, e.) (Reproduced by courtesy of Geological Survey of Canada.)




FARM CREEK EXPOSURE, 7 MILES EAST OF PEORIA, ILL.

3, Bowlder clay, deposited from the melting ice sheet of the last glaciation, fresh on the bottom, weathered on top. Overlain by gravel brought by the melting waters of the receding ice; 2, loess, an eolian deposit during an interglacial period; 1*a* and 1*b*, bowlder clay of an earlier ice sheet. 1*b* is its weathered portion, at least 15 feet thick (down to the dark band in the photograph); 1*a* is a fresh blue bowlder clay. The photograph illustrates a feature common to such deposits of the Ice Age, both in America and in Europe. The earlier glacial bowlder clay (1) is weathered to a much greater depth than the upper one (3), although the latter, at the locality of the picture, became exposed to the influence of the atmosphere about 20,000 years ago. Moreover, the decomposition of the older glacial deposit must have been completed before the region was covered by the last ice sheet, because later this ice sheet and its deposits protected the older bowlder clays against decomposition. Therefore, a much longer time was needed for the interglacial period than the postglacial 19,000 to 20,000 years. (Photo by Rev. Henry Retzek.)

# ELEMENTS OF THE CULTURE OF THE CIRCUMPOLAR ZONE[1]

By W. G. Bogoras

The Polar, or to put it more correctly, the Circumpolar Zone, forms a compact ring of dry land encircling the terrestrial sphere, which is broken only at two points, the first being Bering Strait, the second an opening of sea of much wider stretch along the line Greenland-Iceland-Norway. This second opening forms a passage from the Polar Ocean into the Atlantic just as Bering Strait forms a passage from the Polar into the Pacific.

On the whole, the Circumpolar Zone in its complete extent is subject to similar conditions and so represents an excellent field for the comparative study of a culture, perhaps unique in the world. I may add that the culture of the Polar Zone changes very slowly, being preserved in a very primitive state in the ice and the snows of the North as if it were frozen on purpose for such preservation. On the other hand, that culture is more or less uniform even in its variation. Severe conditions of the climate make tribes even of different origin assume the same inventions and appliances in the struggle for life. Thus we find here uniformity of culture and of general ways of adaptation to the natural conditions of the land.

The Circumpolar Zone is divided by the Polar Circle into two unequal parts: Northward from the Polar Circle extends the tundra, and southward from the Polar Circle lies the forest border, that is, a belt of undersized trees no more than a hundred kilometers in breadth. This belt, from an ethnographical point of view, belongs to the Polar Zone and forms a unit with the tundra. The inhabitants of the tundra, the reindeer, wild and domesticated, and also human hunters and reindeer breeders, leave the tundra for the winter and go to the protection of the forests.

Still farther to the south, from 65° to 60° of northern latitude, extends a zone of dense forest which must be considered as subpolar

[1] Introduction to a university course on the culture of the Arctic and sub-Arctic zones. Reprinted by permission from the American Anthropologist, N. S., vol. 31, No. 4, October–December, 1929.

or subarctic, the natural conditions of which form the transition from the polar to the more temperate climate.

Northward from the tundra extends the ocean, which forms a special zone; we may call it, perhaps, ultrapolar. In America the Polar Ocean, filled with a quantity of large islands and archipelagoes, presents a special cultural zone inhabited by the Eskimo. This zone has as a typical culture of human groups the hunting of sea mammals, of larger and smaller kinds. The tundra, or as it is called in America, the "barren grounds," is actually barren and the scanty human groups inhabiting "barren grounds" have only a very precarious existence.

In Eurasia the relative importance of sea and land is wholly different. The Polar Sea is actually important for man only in the far northeast, where the coast line is clearly cut out and sea game come close to the coast so that the hunting of seal and walrus is very well developed. Farther to the west the sea becomes shallow and the coast low and swampy, so it is mostly left uninhabited and only in certain points, more or less distant and isolated, do we find the northern populations coming to the sea for hunting. Thus on the northern part of the peninsula of Yamal in Siberia and on White Island, adjacent to the shore, there lives a branch of the Samoyed, walrus hunters and bear hunters, almost wholly unknown, which could not be included even in the last census of 1926. No scientist has visited these Samoyed. Professor Shitkoff in 1910 spent a week among them in the middle of August, but he had no time to go over to the northern shore of White Island, where the hunting of sea mammals actually takes place. According to some not very reliable information, the Samoyed must have skin canoes and even larger boats made of planks hewn of driftwood. This summer we sent there an expedition of three young scientists—Mr. V. N. Chernezov, Mr. S. M. Ratner, and Miss N. P. Kotovschikova. They were taken there by the state steamer and left for a year with ample provisions and scientific appliances. So, eventually, they will make a detailed description of this branch of the Samoyed.[2]

Still farther to the west hunting of sea mammals is performed in midocean, also on Spitzbergen and on Nova Zembla, but this hunting is undertaken mostly by the Scandinavians, English, and Russians, with larger ships and with the expenditure of considerable capital.

[2] The expedition came back in 1930. N. P. Kotovschikova died while staying alone on the seashore with all the collections of the expedition, in expectation of the steamer from the west. The expedition brought back valuable material, and reported the finding by V. N. Chernezov of several ruins of half-underground houses of a tribe now extinct, which the Samoyed call "Sirchi." These Sirchi once lived in various parts of the Samoyed territory but have been extinct for a long time. They were a maritime tribe and lived exclusively by hunting the sea-mammoth. Chernezov made some preliminary excavations among the ruins, the results of which will be published in the Memoirs of the Academy of Sciences. It is planned to send another expedition to Yamal in 1931.

On the other hand, the land part of the Circumpolar Zone of Eurasia is developed more than in America and it is covered by a culture more ancient and more productive. The surface of land in the Polar Zone of Eurasia is larger than that of America (not including islands) and represents about three-fifths of the whole surface of the zone.

The Antarctic zone, which represents for geographers a certain important unit, presents very little interest for the ethnographer, since it never had any population and up to the present time remains outside the range of human culture.

The whole stretch of the Circumpolar zone, from North Cape to Bering Strait and from Bering Strait to Greenland, presents similar natural conditions. These conditions may be divided into five groups which are mutually connected but nevertheless represent five different points of view. They are: First, cosmographical or astronomical; second, meteorological; third, geographical (geological); fourth, floral; fifth, faunal. The mutual interaction of these five groups forms the natural base upon which the culture of the far north is constructed. I will try to give brief characteristics of these groups, one after another.

1. Cosmographical or astronomical conditions of the Polar zone are connected with the position of the earth on the ecliptic. According to this position, the north polar circle forms the southern border of the area which has in midsummer the continuous day and in midwinter the continuous night. And so, for instance, on 68°–70° of north latitude we have in the Polar zone three or four weeks of continuous night in the winter and as many weeks of continuous sunshine in the summer. Therefore the transition from night to day in spring and the growth of the daytime in the Polar zone is much more rapid and striking. Since the equinox is the same for all cosmographical zones, the growing of the daytime from zero to 24 hours must go with much greater rapidity than in the south. In this way, after the 20th of March, the day grows as it were by leaps and in the middle of April the glow of the dawn shines throughout the night, and one may work and read or write even at midnight. The snow, however, is not melted as yet and the frost in the night is sharp enough. These conditions produce in the north the so-called white spring, which is the first half of the spring, and lasts much longer than the second half, the so-called green spring. Daytime lasts 16, 18, 20, 22 hours; the night, all ruddy from the glowing sky, 8, 6, 4, 2 hours. The snow melts in the midday sun, but the currents of the water freeze again at midnight. The difference of the temperature is often +20° C. −20° C. These daily changes in temperature work on the psychology of animals and men like a special tonic, awakening

and irritating. Only after the awakening of the spring the living beings are ready for the surplus work and intensive sexual and emotional life of summer.

The second half of the spring, the "green spring," begins suddenly with the breaking of ice in the rivers in June and, in 69°–70° of north latitude, in July. It is accomplished in three days. Birds of passage come in masses; shoals of fish from the ocean enter the rivers; trees and bushes are budding and sprouting; and everything is green. So nature, the vegetable and animal life, passes from the white spring with its night frosts almost immediately into full summer. Summer comes like a sudden leap, like a favorable storm, like a yearly mutational period, or some natural revolution.

2. Meteorological conditions are no less remarkable. While the cosmological conditions refer to degrees of northern latitude, to the continuous day in summer and night in winter, meteorology deals with questions of the degree of frost, of the intensity of wind and winter storms, and also of the thickness of the ice sheet and the snow layer in the winter. The underground layer of the soil is on the whole always frozen, and large areas of this ever-frozen ground spread far southward even into the Temperate Zone. In the summer the ground thaws out, but, even in the southern part of the Yakutsk Province, only for three-quarters of a meter, and close to the Polar Sea for half a meter or even less.

On the other hand, the ice sheet on the lakes and on the rivers is 2 meters thick or even more. When you want to pierce the ice that thick, for setting nets or simply for taking water, you have to cut with an ice pick a round funnel 3 meters in diameter. The person working will gradually sink down and then completely go under the surface of the ice; only the upper portion of his ice pick will be seen; and still he will have no water and the ice under his feet will be absolutely dry. Even when cut through, the water hole must be cleaned up and pierced anew twice a day, morning and evening, or else the ice sheet will close again and the hole will shut together at least for 2 feet in thickness.

Then, again, on account of the ever-frozen ground, the rivers begin to freeze not only from above but also from beneath. Very soon the water flows as if encased in a round tube of ever-frozen material. The surface sheet of the ice is formed of small tablets, thin and brittle as the thinnest glass, but on the very bottom in the water begins to form the bottom ice, the so-called *salo*, which has the shape and the consistency of half-dissolved snow. In this double manner the river freezes with the utmost rapidity. Shallow currents in the mountains in more quiet places freeze to the bottom. Then the water flows on the surface of the sheet, forming the so-called *nalhed* (ice surface water). This water is immediately covered

with a new sheet of ice, bright and smooth as polished glass. So in January one may very well break down through this newly formed ice into the coldest water up to the waist and further.

The frost in January is sometimes 70° C. When a person spits on the ground, the spittle falls down upon the snow like an arrow of ice. Breath comes out of the mouth with a peculiar rasping sound from the smallest particles of vapor freezing into sleet. A horse is surrounded with a thick cloud of its own breathing. A man's face, fingers, and toes are frost bitten quite unawares. This happens 20 times in a single day after you have succeeded in rubbing them again into warmth.

The breaking of the ice on the large northern rivers has also some peculiar features. Quite suddenly, the ice sheet breaks into huge blocks obstructing the current. The water rises immediately. Blocked ice in all streams cuts away great pieces of the steeper banks, producing genuine excavations. Stretches of surface ground cave in, trees and all. So the breaking of the ice with subsequent blockings and risings of the water develops on a scale truly majestic and gigantic. River shores, from the upper currents down to the very mouth, are covered with masses of floating ice drifted ashore. Since rivers of northern Eurasia flow chiefly from the south northward, their shores down to the 70° of north latitude and even to the very ocean are covered with large supplies of driftwood, good for fuel and lumber. Practically speaking, the lower parts of the greater Siberian rivers, even in the middle of the tundra, are surrounded by the artificial protection of the forests.

Joint interaction of astronomical and meteorological agents bring forth a marked influence on various sides of human culture.

For instance, in the spring, during long, almost endless days, the upper surface of the snow thawing under the mid-day sun and freezing again in the night, gradually turns into a hard crust, the so-called *nast* in the local Russian dialect. This snow crust is of the highest importance for the conditions of spring hunting, of the so-called meat-bringing character: Dog, man, and wolf may easily run upon the surface of the snow, especially man supporting himself upon skis. But heavier wild reindeer and elk break through into the inner, soft snow, cutting their legs against the sharp edges of the broken crust, and so they become helpless against their pursuers. The Tungus and Yukaghir in the north, the Gold and the Samaghir in the Amur country, provide the better part of their food lasting for a full quarter of a year by just this spring hunting of elk and reindeer on the hard snow crust.

3. Geographical and geological conditions refer to the configuration of the surface of the land and to the character of the ground. The

northern part of the Polar zone presents the tundra, as indicated above. Most of the tundra is quite flat and damp, soaked with water like a very sponge, and having a covering of vegetation, chiefly of reindeer moss, which is a kind of lichen. Still there are other varieties of tundra covering the lower hills and even a part of the mountains. These hilly tundras are much drier than the flat country. The tundra stretches are interrupted in some places with rugged mountains, quite naked and desolate, which at certain points, come into the sea, forming huge capes. These capes serve as landmarks over the long extent of low, slimy seashore. Such are, for instance, in Eurasia, North Cape and Cape Taimir, East Cape, Indian Point, etc.

Still, I should mention that all varieties of tundra and of barren mountains do not belong to special localities in the west or in the east. They are interchanging through the whole extent of the Polar circle, appearing again and again in Europe, in Asia, and in America, and some cultural phenomena appear in the same way spot wise on the whole stretch of the Polar area; for instance, snow goggles and a special ring for protecting the hand against the bowstring, etc., have various forms, but each of these forms appears again and again in localities separated from each other by hundreds and thousands of miles.

The influence of these geographical conditions on human culture is also very important. Let us take the question of communication. In winter, throughout the north, communication is carried on with sledges; in summer, the southern hilly part of the zone presents difficulties of communication almost insurmountable. The inhabitants chiefly various branches of Tungus, may wander around only on reindeer back or even afoot.

In the northern part of the country, quite flat and covered with a maze of rivers and lakes, all having connection, walking on foot is quite impossible. The usual means of communication is the canoe of varying make, a dugout or a combination of three thin planks, less frequently a birch-bark affair—all these are propelled either by paddling or by special poles thrust into the bottom of the stream, which is usually shallow. The breaks between the waterways are narrow and damp, so the paddler is able simply to push along the wet grass from one watercourse into another. In this way it is possible to pass over from one fluvial system into another even without leaving one's canoe for a single moment. If you were to look on such tundra country in the summer from an airplane, it would appear to be covered with an endless net of blue veins filled with water and combined into one system. You could perhaps make a journey from the Obi River to the Kolyma having on your feet only the so-called dry-land boots, which are utterly unfit for walking in the water, and you would

not spoil your dry-land boots, because for overnight stopping you could pick out some convenient dry little place. In extra cases you could take off your boots and wade through the damp grass barefoot.

4. If we take up now the botanical conditions, we find them also exhibiting several variations. The tundra has a flora of its own. The forest border is of course very different, and the sub-Arctic dense forest is different from both. These three variations extend throughout the whole Polar zone. The tundra has chiefly the lichens and the genuine mosses, some tough sedge grass and patches of undersized shrubs so rough that they can burn and serve as fuel without any drying. The forest border has more bushes and even a kind of scrub. Undersized trees with crooked trunks and boughs out of shape form islands which on the south join gradually without interruption. Of black wood species there are the birch, the alder, the aspen, the poplar, and several kinds of willow. Birch and willow, and of the conifers the cedar, assume a creeping form. The birch and willow have also some drooping forms with branches hanging down.

Of the conifers there are the larch and the pine, the spruce, and less frequently, the Siberian fir. The larch tree in the forest border quite frequently gets a crooked trunk bent into a kind of spiral, the so-called, in local Russian, Кренъ (KREN). The outer layer of that "kren" has a much harder consistency and may therefore be applied for various products.

The sub-Arctic forest has all the species mentioned above, but they are more stately and the forest much more dense than on the northern edge.

As to the animal species, the reindeer feeds on lichen, which is also called reindeer moss. The elk lives on the birch and the alder groves, feeding on leaves and bark. The squirrel requires conifers, since it feeds upon their cones. Even in the growths of the creeping cedar, which in English is called stone pine, squirrel and sable fare quite well, the squirrel feeding on cedar cones and the sable on squirrel.

For man, the botanical conditions are of direct importance as to construction materials for huts and the fuel for heating them. The forest even on its border represents the best protection against the snow tempests raging in winter. The flat tundra is open to every winter tempest and travellers often are buried under the snow, in the literal sense of the word, as I had occasion personally to experience over and over again. We were buried in drifted snow for 24 and even 36 hours, after which we had to cut our way outward through the snow hardened by the wind like some solid marble. Dense forest of the more southern belt gives cover against the fiercest storm, and the snow in the forest lies soft and downy like a feather-

bed. Therefore, the skis in the forest region are made of thin wooden planks, broad enough not to sink through the snow. Skis of this type are not good for the tundra. The hardened, uneven snow surface of the tundra requires a special shape of ski plaited of cord, the so-called "raven claws." The natives say that skis of this shape leave on the snow traces like the tracks of raven claws, but more probably this name is connected with some variation of the raven myth so important in the folk lore of the Bering region.

5. Zoological conditions of the north are as follows: Since the natural resources of the north from the human point of view are mostly of zoological character and the people live on an animal diet, we must discuss, one after another, first, sea game, mammals, and fishes; second, land animals, wild and domesticated; and third, birds.

The northern zone is almost wholly unfit for agriculture, even for the gardening and raising of vegetables. The principal form of the culture is either the hunting of wild animals or the raising of domesticated ones. Both forms of economics are based on faunal considerations. One deals with wild animals and the other with domesticated. The difference from a general point of view is not very important, and the raising of animals is only a result and development of hunting of them. The breeding and the growth of animal life in the north, as elsewhere, is based first and last on the abundance of food. The northern zone is not very rich in the number and variety of species, but all the richer in the number of individuals of the same species and in the celerity of breeding and increasing of animal life. The abundance of animal life in the north in some cases is almost beyond imagination, surpassing the chances of the more southern latitudes. From the economic point of view the animal supplies of the north are quite sufficient not only for the support of its inhabitants but also for export to southern regions more densely populated than the north.

What is the reason for the faunal abundance of the north? As yet we hardly know any answer to that question. In regard to the sea fauna, it is known that the Arctic seas abound with plankton, which forms the base and the staple food for all fishes not strictly carnivorous. The studies of Russian scientists in the White Sea and in the nearest part of the Arctic Ocean try to establish that part of the northern sea is far better supplied with plankton than the seas of more southern latitudes. In connection with this, fish are more abundant in the north. Moreover, innumerable sorts of fishes living in temperate and warm zones come over to the north and enter northern rivers in order to spawn and propagate. As far as I know, the great rivers of the South, the Amazon, Rio de la Plata, and Mississippi, having their own fish population, have not such masses of wandering fish entering their mouths from the ocean.

The same refers to the birds of passage. Numberless flocks of waterfowl of all species come to the north even from the hemisphere across the Equator. According to the conditions of the climate, they may spend only four months in the north against eight months in the south. Nevertheless the north is their usual breeding place. Here they have their mating and nesting periods, and the short summer time suffices even for the growing up of the young who, after that, depart along with the older generation toward the south, which is wholly unknown to them. To be sure, all the northern land is covered with bogs and watercourses and there is room enough for the breeding of the young. Nevertheless this instinct of migration is very remarkable in the birds of passage. One must presume that the migration of birds, with all instincts and exertions referring thereto, is not exceedingly ancient. It could have originated only in the Quaternary period when the configuration of the mountains and the larger areas of land, also the distinctions of the climates, already existed on the same plan as at present. In the Tertiary period the birds of that time probably had no need to migrate northward. The climate of the terrestrial globe was more uniform, and especially in the north it was moderate and even warm.

1. Most abundant of all sections of animal life in the north is the class of fishes. Sweetwater fishes also abound in the north. Such are for instance the pike and the burbot. Burbot are caught in such masses on the Kolyma and the Indighirka Rivers in the time of early spring that the burbot livers cut out and frozen together form big loads carried across the country with dog teams and pack horses. I have seen caravans of pack horses each carrying frozen burbot liver in two rectangular blocks of 50 kilograms. But maritime species, namely, the salmon, are still more abundant. The migratory salmon of the north may be divided into two large groups: Salmon of the genus *Coregonus* belong to the Polar Ocean, and enter the rivers such as the Kolyma, the Indighirka, the Yana, the Lena, the Yenissei, the Obi. Salmon of the genus *Oncorrhyncus* belong to the North Pacific Ocean and enter the rivers beginning from the Anadyr down to the Amur. It is curious to note that Kolyma and Anadyr, the two great rivers of the northeast, which belong to the same ethnical and cultural area and the sources and headwaters of which meet together in the mountains, have fishes of essentially different genera. Kolyma has *Coregonus* species entering from the ocean, and some sweetwater species of *Oncorrhyncus*. Anadyr, on the other hand, has *Oncorrhyncus* entering from the ocean and some species of *Coregonus* of the sweetwater branch. The species of *Coregonus* have white flesh, those of *Oncorrhyncus*, pink flesh. Both groups in the whole period of spawning do not care for any food and even do not

care much for their own life. But *Oncorrhyncus* is much more reckless. In ascending the rivers upstream the fishes of these species perform feats truly acrobatic, since they leap in the more shallow places from stone to stone, wriggle on through damp grass, and in other places mount the waterfalls. Most of their shoals do not return to the ocean and they perish in the river soon after spawning.

White salmon of the Arctic Ocean as a rule preserve their life after spawning and descend the stream back to the ocean, though quite exhausted after the exertions of their sexual life.

According to these points of difference, the pink salmon of the Pacific must be more numerous than the white salmon of the North, and also much easier to catch. Their greater number makes for the great annual loss of life that forms one of the necessary links of their breeding process. After the spawning the pink salmon species, for instance the dog salmon, changes so much that it is difficult to recognize it as the same kind of fish. Not only does its flesh become lean and tasteless, but its whole shape changes. Its jaws become crooked, forming a kind of beak, and the back assumes a form of hump, like the hunch salmon.

This fall salmon is very poor eating, even for the dogs. On the other hand, dogs in the Pacific region as well as foxes, wolves, and even sables and ermines, try to catch salmon directly in the water, when it passes on mad with the desire of spawning. Anadyr dogs, when sold to Kolyma people, in their first polar summer would wade into the water, trying all the time to catch some salmon. They would usually snatch some smaller piece of wood and then desist. It shows very clearly the difference in the way of catching pink salmon in the Pacific and white salmon in the Arctic. Northern salmon are not so abundant nor so reckless as to be caught out of the water by the very first dog.

On the other hand, on the rivers entering the Pacific thousands of pink salmon, dead from exhaustion, are carried by the wind directly to the river banks, where they form ultimately strata of dead fish, which are covered by the early snow of October. From these natural storehouses bears and foxes feed throughout the year, and men take food for their dogs.

Whole tribes and settlements on the shores of the larger rivers of Siberia live exclusively by fishing. This way of living makes the village and the house permanent and the people sedentary. On the other hand, the culture of these tribes is primitive, and psychically the people are passive. The struggle for life is not very fierce. Food is always extant. It is caught in a manner more or less primitive, for instance with fishing weirs, when large creels of willow are choked full with the best fish, or with long nets drawn across the river, which also regularly are white with fish caught

in every mesh of the tressed bark or linen thread. Some Chuckchee and Koryak on the Pacific shore do their fishing with a short net pushed into the water by means of a long pole 10 m. in length. Since such long poles are but seldom met with, shorter pieces of wood are spliced into one single pole with much ingenuity and even with art. The net when being thrust into the water catches immediately about 10 fat fishes 5 to 7 pounds in weight. The fisherman draws the net back, takes the catch, and thrusts the net into its former position. In this manner he can get in 24 hours, without a boat, and standing on the shore, some 200 or 250 fishes—500–700 kilograms. This fishing work, of course, is quite exhausting and it is carried on only by the poorest of the natives. The method of such fishing is truly paleolithic, inasmuch as it presents almost a simple gathering of the natural supply of food.

A very important detail of the economic and political life in the north is represented by the fact that the Russian Cossacks, hunters and traders, a counterpart to the Spanish conquistadores, since they also have conquered these immense lands in an almost incredibly short time, soon after that settled in the North just like fishermen. The first condition of life for them was an immovable house with a regular couch and regular heating. They were averse to wandering around the tundra with the herd of reindeer just as they have objected to the constant wandering of cattle-breeding nomads. So the Cossacks intermingled with the fishermen, took wives from among them, and assumed from the beginning their way of supporting life on fishing and hunting. Still, psychologically the hardy conquerors were wholly different from the passive and indolent northern fishermen. But since the women in the new settlements of these Russian creoles and halfbreeds and Russified natives were of local origin, the economic and psychical ways of the natives were soon prevalent and the fierce energy of the Russian invaders was soon gone. If we compare the earlier reports of the Cossacks with the Siberian *Voyevody* (governors) for instance from the fifties of the seventeenth century, with the reports of their immediate successors half a century ago, we find a very marked change. Early reports relate:

> We were 17, we descended the river looking for some source of fame and advantage to His Majesty the Czar, and then we found the native post. It was large and strongly fortified, full of armed men. We fought against them from morning to evening. And God gave us luck; we conquered. We have killed all the warriors and burned down the fort. We took captive women and children and took a multitude of costly furs and ready-made clothes.

In the later reports of the beginning of the eighteenth century, we read on the other hand:

> Our boats are small and the sails are weak. And we do not know how to build large ships, such as were constructed by our fathers.

The change in the psychology of the Russian settlers under the influence of the Russianized native fishermen is the real cause why the Russian parties of Cossacks and soldiers in the eighteenth century could not subdue the fierce Chuckchee tribe. The party of Major Parlatsay in 1747 was utterly defeated and he was taken captive and tortured to death simply because the ancient warlike ardor was not there.

Up to the present the mutual relationship between the Russianized natives and the Chuckee reindeer breeders is quite peculiar. From the economic point of view the Chukchee, as the animal breeders, are of a higher stage than the fishermen of the Russian villages, while in other things the Russian and Russianized natives are much higher than the Chukchee. In this way the Russians who were and are the domineering race, at the same time were living like mendicants and parasites on the boons from the wealthy reindeer breeders of the tundra.

2. Hunting of sea mammals, in contrast to fishing, is practiced on the sea, often even amidst the open water, or on the brink of the ice fields about to break up, but never by hand from the shore. The psychical character of the maritime hunters is quite different from that of the fishermen. Northern hunters are mobile, always on the alert, ready to go away into the open, given to wandering for many and many miles. It has been the custom of the maritime Chukchee and the Asiatic Eskimo to go over to America from very ancient times. Even now they make quite long trips across the ocean. The Koryak are much more passive, but they are fishermen rather than sea-mammal hunters.

The difference between the fishermen and hunters of sea mammals is expressed in the choice of the site even on the sea coast. The settlements of fishermen are on the river shore, in the inner estuaries, or on the inland side of some adjacent island. The settlement of a hunter of sea mammals is established on the outer capes or on the windy side of an island where there is always a chance for the sudden pursuit of a group of seals or a big walrus or even a whale.

The species of sea mammals are more or less alike throughout the Polar ocean of Eurasia—whales of various kinds and sizes, one or two with precious whalebone, others giving only meat and blubber, white whale and killer whale, and two varieties of walrus: Of seals, ground seal, *Phoca barbata;* ribbon seal, *Phoca fasciata;* and of smaller seals, *Phoca greenlandica*, *Phoca vitulina*, *Phoca phoetida*, and *Phoca haspida.* I could mention several names in Russian creole and native languages, but the trouble is that these names change from one district to another, being given at one time to one species, another time to another. The white polar bear is also to be included among the sea mammals. Of these the natives distinguish several varieties,

one not very aggressive in meeting with man, another fierce and bloodthirsty. Sea-mammal hunting is combined with reindeer breeding among the Chukchee and with fishing among the Koryak and Kamchadal.

Overland animals are hunted by a series of overland tribes among which are the Tungus in 12 groups.

Overland hunting represents two branches, one for meat consumption, referring to the herbivora, and another for the fur market, referring to the carnivora, including the smaller kinds, such as sable, ermine, etc. Before the advent of the Russians hunting for meat prevailed; people did not know what to do with furs of these and other species, while they had no other food except the meat of the game.

The first place among the meat-supplying species belongs to the reindeer, wild as well as domesticated. Wild reindeer are on the constant decrease. The domesticated herds, notwithstanding the losses of the last 10 years, still contain more than 2,500,000 animals. The mutual attitude of wild and domesticated herds is more or less exclusive to each other. This was demonstrated in the middle of the nineteenth century, when the Chukchee, on the invitation of the chief officer of the Kolyma, receiving at last assurance that no harm should happen to them, moved with their herds westward even across the Kolyma River to the western tundra, and the herds of wild reindeer had to leave the pastures of that country and go elsewhere. Some of them migrated to Anadyr. Most of them were dispersed and destroyed.

As a result the Yukaghir and the Chuvantzy Tribes, who lived on the eastern affluents of the Kolyma and relied for their sustenance on yearly hunts of the numerous herds of wild reindeer in the spring and in the fall, were suddenly deprived of their means of existence and perished by direct starvation. Some remnants of them emigrated to the lower Kolyma River and took to fishing. Those who stayed on the spot in some cases were driven even to cannibalism.

The other meat-supplying species is the huge elk of Siberia, now mostly exterminated. The last remnants of the former abundance are to be found in the southern course of the Kolyma River and in the valley of the Amur.

The brown bear in the forest land, the hare on the tundra, the mountain sheep in mountainous regions, even squirrel, marmot, and spermophillus, also serve for food. The Maritime Chukchee and the Asiatic Eskimo consume the meat of the polar fox, and the Reindeer Chukchee occasionally eat mice, but all these supplementary sources are of small importance.

By the way, the hunting of sea mammals belongs to the first branch of meat-producing character. Meat, oil, and blubber—these are the

principal products of the hunting of sea mammals. Walrus hides and sealskins are used chiefly for the needs of the hunting people. Only the fur seal, the polar bear, and the very rare sea otter supply pelts that are marketable.

The second branch of the overland hunting developed only since the advent of Russian merchants and officers, or in the American part of the Polar zone with the advent of English, American, and Canadian traders.

Three hundred years ago the northern countries were teeming with costly sable and ermine. Now the hunting of such fur-bearing animals is greatly reduced. Squirrels and polar foxes alone go on breeding, thanks to their wide distribution and fecundity.

At all events, several groups of hunters in the north exist in a peculiar way. They can not get enough meat from the meat-supplying species, so they live exclusively by hunting the fur bearers, chiefly the squirrel. They sell the pelts, of whatever kind they succeed in getting, and then buy some grain of the lowest quality which they grind by hand grindstone and make into unleavened cakes. So these hunters practically have passed from their natural economic state to a condition in which exchange predominates. The Russian peasants of the neighborhood live in a condition of natural economics, for they consume the best part of their own harvest and sell only the surplus of the product.

I have tried to indicate five groups of natural conditions, one after another, and the human culture developed in these surroundings on the basis of the conditions as enumerated. Man in the north lives wholly under the power of nature, and if we take three groups of cultural phenomena—the material, the spiritual, and the social culture—we notice that all of them are influenced with great force and strictness by several groups of conditions mentioned above.

I will cite two examples, referring, respectively, to the material and the spiritual culture of the northern tribes.

The first is connected with the question of fuel. Fuel is scarce on the tundra and the inhabitants had to work out a method of heating without any fuel at all. The Chukchee, the Koryak, and the Asiatic Eskimo have their sleeping room heated chiefly by the accumulation of human natural heat, which can even be regulated by accepting new guests or, in case of excessive temperature, by trying to send away some who constitute the surplus. The Eskimo construct for heating purposes an underground house with an inner sleeping room, the protective walls of the underground room being made of earth and sod.

The Reindeer, and partly the Maritime Chukchee, construct their huts and the inner sleeping rooms from the best reindeer skins. This translation from one material into another reminds one of the

Chukchee language, which is also the transfer of the Eskimo morphology into some unknown linguistic elements of ancient Asia.

The second example refers to the spiritual culture. It deals with the folklore. Northern people of whatever race or culture stage, having little else to do throughout the endless nights of winter, fill their leisure with working out the elaborate schemes of stories adorned with the finest embroidery of imagination. That accounts for the development of folklore among the northern tribes and even for the development of Scandinavian epics among the Norsemen in Iceland in the twelfth and thirteenth centuries.

With the Maritime Chukchee and Asiatic Eskimo the folklore develops in conditions of a different kind. These two tribes often even in the midst of winter, being short of stored provisions, must get their sustenance from the continuous search for seals. A fierce winter storm, keeping them at home sometimes for several days, may put them on the brink of starvation and what is still worse, deprive their lamps of the light-giving oil necessary for dispelling the oppressive darkness. And sometimes the best hunters will come out through the storm always in pairs, joined together with a long thong in order to feel always sure of the mutual touch. The folk-tales are full of such desperate attempts when the people begin "to get lean in their marrow bones." These stories are usually repeated at night, when the inmates are pent up within the sleeping room, and they are considered as the best incantations against the storm. The close of the tales is also an incantation of its own, "Wahó, yóočhin tínmûgan," "Oho, I killed the tempest!" By the way, stories related during the winter storms must refer chiefly to storms, to work against them the more efficiently. The connection of meteorological conditions with the evolution of folklore is quite clear.

Some of the old women know so many tales that they are able for a month or more to present a new tale every day, intertwining together the subjects and plots with great art.

Out of these natural conditions the culture of the North has developed. Though we call it primitive, we must not compare it with the most primitive culture of some tropical tribes, such as the Botocudo or the Bushmen. These last tribes go around quite naked, have no house to speak of, and feed on anything that comes their way and which they can gather without much effort in the wood or on the prairie. Their economics belong to the earlier stage of the so-called collector type. They store no provisions, and notwithstanding the abundance and even the lavishness of natural supplies in the South, they pass from one spell of hunger to another, interspread with a much shorter period of reveling in plenty.

Now in the northern conditions, one can not go on without clothes, house, and storage for the winter. Even primitive man must take care of his future, otherwise he will die. This is why the culture of the North is not only of a well-developed type, but even has a special development.

The Eskimo culture, which represents the best developed variation of the culture of the North, abounds in implements and accommodations of amazing fitness. Some of these were imitated not only by their nearest neighbors to the south, but even by the civilized part of humanity, such as the Russians and Americans. The whaling harpoon is an Eskimo creation, but it was imitated by almost all the tribes which practice whaling.

In the classification of the cultural types of the North, we find some types of local origin, such as fishing, hunting, reindeer breeding, and other types of a higher culture, which came to the North in later times brought over by immigrants from the South. I will start with the classification of the indigenous cultures.

As for implements and weapons with some few exceptions, the tools of the North are Neolithic. To be sure in the last hundred years some metal work and the art of weaving has spread among the natives in imitation of the Russians, and, in the far east, of the Chinese. Still, even the shape of the tool or the weapon made of metal, curiously imitates the form of the stone or bone implements. For instance the Reindeer Chuckchee use instead of the axe a small hatchet, an actual tool of the Neolithic period. The local blacksmiths of Russian origin prepare such hatchets especially for Chukchee use. Nevertheless, most of the northern tribes have even some blacksmiths of their own, capable at least of mending the simplest iron implements. Some of these tribes still have an idea that the art of the blacksmith requires skill and knowledge of no common kind. The Chukchee, for instance, in some tales borrowed from Russians describe a young prince, the son of the king, as having a face as intelligent as a blacksmith's.

According to the chief pursuit bringing the means of life, the northern culture may be divided into several types. I must mention that notwithstanding their primitive character, the northern culture created two branches of animal breeding, the breeding of domesticated reindeer and that of driving dogs, peculiar to the northern zone. Within that zone, however, it is imitated from the native tribes by the most civilized immigrants of later arrival. The American settlers in Alaska imitated Alaskan Eskimo dog driving and Siberian reindeer breeding, which has prospered and increased at such an amazing rate.

Also in fishing and hunting, the northern natives have created various implements, afterwards imitated not only by later immi-

grants from the South, but also passed over to the neighboring people of more southern latitudes. Such is for instance the small Siberian trap for ermine and other small game, which has spread through the whole temperate zone of eastern Eurasia down to the Bashkir and the Kirgiz. The same is the case with the larger striking trap for foxes, the deadfall for foxes and walrus, etc.

Moreover, we can see that in the economics of hunting the fur-bearing animals the northern natives of the so-called primitive tribes are the most circumspect in looking out for the future. While the Russian invaders from the South ruthlessly destroy the best cedar forests with their axes or careless fires, and exterminate the "green" squirrel when the "unripe" peltry is not fit for selling, the Tungus or Ostyak, when undisturbed by neighbors, will proceed with much more forethought, trying to leave some of the foxes and squirrels for his last days and even for his children.

I will only repeat one of the paragraphs of my memoir on the "Conditions of Life of the Lesser Tribes of the North," presented in 1923 to the Central Executive Committee of the Soviets:

> The principal riches and resources of the North are not represented by the numberless shoals of fish, nor by the endless droves of wild geese and swans, nor by herds of reindeer, wild and domesticated, and not even by the fields of coal or veins of gold to be brought into the mining work; the real riches of the Far North, the most important of all, are represented by the northern people, who are the only means and agents to work out profitably all the natural resources of the North and to bring them in touch with human culture. Without the northern tribes, the riches of the North will be left without use and without workers.

After these preliminary remarks, I will indicate the chief types of the northern culture as the following:

1. Fishing.
2. Hunting, with two subdivisions: (a) Meat-providing branch; (b) fur-providing branch.

The other subdivisions, according to areas of exploitation are: (1) Overland hunting; (2) sea-mammal hunting.

Economic pursuits, as mentioned above, less frequently appear in the exclusive form, but oftener as combinations of two or three types, with one prevailing, or with two or three of equal importance.

So, for instance, the hunting of fur-bearing animals is combined either with fishing, or with overland meat-providing hunting, or with hunting sea mammals. Some tribes combine everything—fishing, overland meat providing, hunting of fur-bearing animals, and hunting of sea mammals. Such are the Maritime Koryak and the Gilyak. The Maritime Chuckchee have very little fishing, since the Chuckchee Peninsula has no rivers for the fish to enter for spawning, and salmon do not go this way; and, of course, the inland Tungus or Yukaghir have no hunting of sea mammals.

3. The third type refers to the higher cultural stage, since it deals with the breeding of domesticated animals, viz, reindeer.

Still the breeding of reindeer in all its ways and methods is so primitive as to rank on a level with hunting and fishing.

Moreover, in several cases, the reindeer breeders, though economically better off, are in other respects even behind their fishing or hunting neighbors, who for instance practice various handicrafts and then exchange their artifacts for the produce of reindeer breeding.

Reindeer breeding also enters into combination with hunting and fishing. In northern Eurasia, as a general rule, the tribes of hunters do not wander afoot, but have some reindeer to supply the necessary means of locomotion. The Tungus hunter can not very well do without riding reindeer. Reindeer mounts supply the Tungus with the means for wandering over immense areas, and only by means of the riding reindeer could the Tungus spread over 10,000 kilometers in extent from the eastern affluents of the Obi River down to Kamchatka and Saghalien, and from 70° of northern latitude in the tundra down to the south, beyond the Chinese border. On the other hand, extensive reindeer breeding does not come very well into combination with fishing, because fishing presupposes a stay on the shores of lakes and rivers, which have not sufficient lichen pastures and are too much pestered by mosquitoes and reindeer flies. Extensive reindeer breeding presupposes continuous wandering with the reindeer, while fishing is much more sedentary.

At the same time, the better half of the northern tribes include both types of pursuit practiced side by side, reindeer breeding and fishing, or, with the Chuckchee, hunting of sea mammals. Some tribes are divided into two branches, the reindeer breeding, who wander throughout the tundra, and the sedentary, dwelling close to the water and out of the water. The ways of life of both these branches are often not only different but even antagonistic, as with the Chuckchee, where the driving dogs of the sedentary people represent the bitterest foe of the reindeer herds, and so the reindeer breeders can not even come into the neighborhood of the Maritime villages.

Still, both parts of the tribe are conscious of their natural tie and consider themselves to be of the same tribe. They intermarry freely and in case of need act as one unit. It is open to question whether they represent one natural unit practicing two pursuits of life, or two different units who have brought out two different ways of life and then gradually blended.

# THE TELL EN-NASBEH EXCAVATIONS OF 1929
# A PRELIMINARY REPORT[1]

By William Frederic Badé
*Director of the Palestine Institute and the Tell en-Nasbeh Expedition*

[With 8 plates]

## INTRODUCTION

Tell en-Nasbeh is the modern Arabic name for a commanding hill which lies 7 miles (13 kilometers) north of Jerusalem. The main road of north-and-south travel between Jerusalem, Nablous (Schechem), Nazareth, and Haifa, passes close to the eastern base of the hill. But during Graeco-Roman times, and presumably throughout earlier periods of Palestinian history, the main line of communication passed through the narrow valley which lies along the western edge of the hill. The latter was ideally situated for the erection of a fortress city commanding the southward approaches to Jerusalem. A number of years before the inauguration of the present excavations, in 1926, several close students of Palestinian geography, among them R. P. L. H. Vincent, W. J. Phythian-Adams, and Prof. Gustav Dalman, have expressed their conviction that the mound in question covers the remains of Mizpah, which anciently belonged to the tribal territory of Benjamin (Judg. 20:1; I Sam. 7:5; 10:17; I Kings 15:16ff.). Three seasons of excavation since then have brought to light much evidence which supports this identification. The city was completely refortified about 900 B. C., a fact which agrees with the notice in I Kings 15:22, that Asa, King of Juda, fortified Mizpah against the attacks of Baasha. There were uncovered, among other things, the foundations of a sanctuary and a place of sacrifice such as Mizpah must have possessed according to Biblical accounts. The last reference to Mizpah in ancient records (I Mac. 3:46) states that the place was used as a stronghold by the noted Jewish military leader, Judas Maccabaeus. Extensive Maccabaean structures, dated by coins, were found in 1929. The excavations are to be continued in 1932.

[1] Reprinted by permission, with author's revision, from Quarterly Statement of the Palestine Exploration Fund, January, 1930.

During the excavation seasons of 1926 and 1927 we had succeeded in clearing a large portion of the southern end of Tell en-Nasbeh, including the great outer city wall (Bronze Age) and a narrower and still older inner wall. At one point we found unmistakable indications that a gate had pierced the Bronze Age wall, but so far up in the masonry that its subsequent destruction carried away also the remains of the gate. During the first phase of the Iron Age, when the remains of the city wall lay buried in débris, a road led over the top where the Bronze Age [2] gate had formerly been. There are good reasons why the road should have clung to this particular spot; within, it was the approach to the sanctuary precinct; without, to the spring.

## THE NORTH END

In 1929 we laid our plans for an exploration of the Tell from the north end. Contours revealed by the German airplane photograph seemed to indicate the existence of a gate at that end. Operations were begun on March 15 by cutting a wide trench through the extramural débris along a line at right angles to the clearly marked edge of the city wall. On reaching the outer face of the wall I found, to my great surprise, that it was leaning outward at so sharp an angle that it was impossible, even after shoring it up, to remove all the débris without endangering the lives of the workmen. At one point the talus of rock leaning against the wall showed unmistakably that it had resulted from the outward collapse of an upper section of the wall. Not far from its base were the remains of a retaining wall and beyond it a moat excavated in the limestone bedrock. This

[2] In his attempt to prove that Tell en-Nasbeh could not have been the Mizpah of Benjamin, Probst H. W. Hertzberg (cf. ZAW, 1929, pp. 195–96) has fallen into strange errors. He overlooks the fact that the gate found in 1927 at the south end of the Tell was in the Bronze Age wall, and therefore can not be used for an argument about Israelite use during the Early Iron Age. The Israelites had a well-marked road over the top of the demolished Bronze Age wall at the point where the Bronze Age gate had formerly been. The road made a direct approach to the sanctuary precinct.

Equally beside the facts is his assumption that the sanctuary found in 1927 did not antedate the ninth century B. C. On p. 15 of my preliminary report, I have stated explicitly that both the first and the second phases of the Iron Age (1200–586 B. C.) were well represented by house levels and cistern deposits, and the sanctuary was a part of both of them. On p. 38 I also refer to evidence of the probable Maccabaean use of the high place. Last summer's excavation had made this a practical certainty, for extensive Maccabaean levels were uncovered, which integrate with Maccabaean surface remains found in and around the sanctuary in 1927. We have also good evidence to show that the use of the high place reaches back into pre-Israelite times. In AL22 our general map (cf. frontispiece of preliminary report) exhibits remains of what was doubtless an earlier sanctuary, not under, but beside, the later one. Hertzberg's reference for his dating of the sanctuary into the ninth century was based on a quotation from a monthly expeditionary news bulletin of June 1927, in which no attempt was made to fix a comprehensive date for the sanctuary, because the excavations were still in progress. In short, his two main contentions, so far as the writer's preliminary report is concerned, are completely erroneous. For nothing is better established than that Tell en-Nasbeh was an Israelite and Jewish city from 1200 B. C. to the beginning of the Christian era, so that the sanctuary still remains der gewichtigste Grund against Hertzberg's general argument.

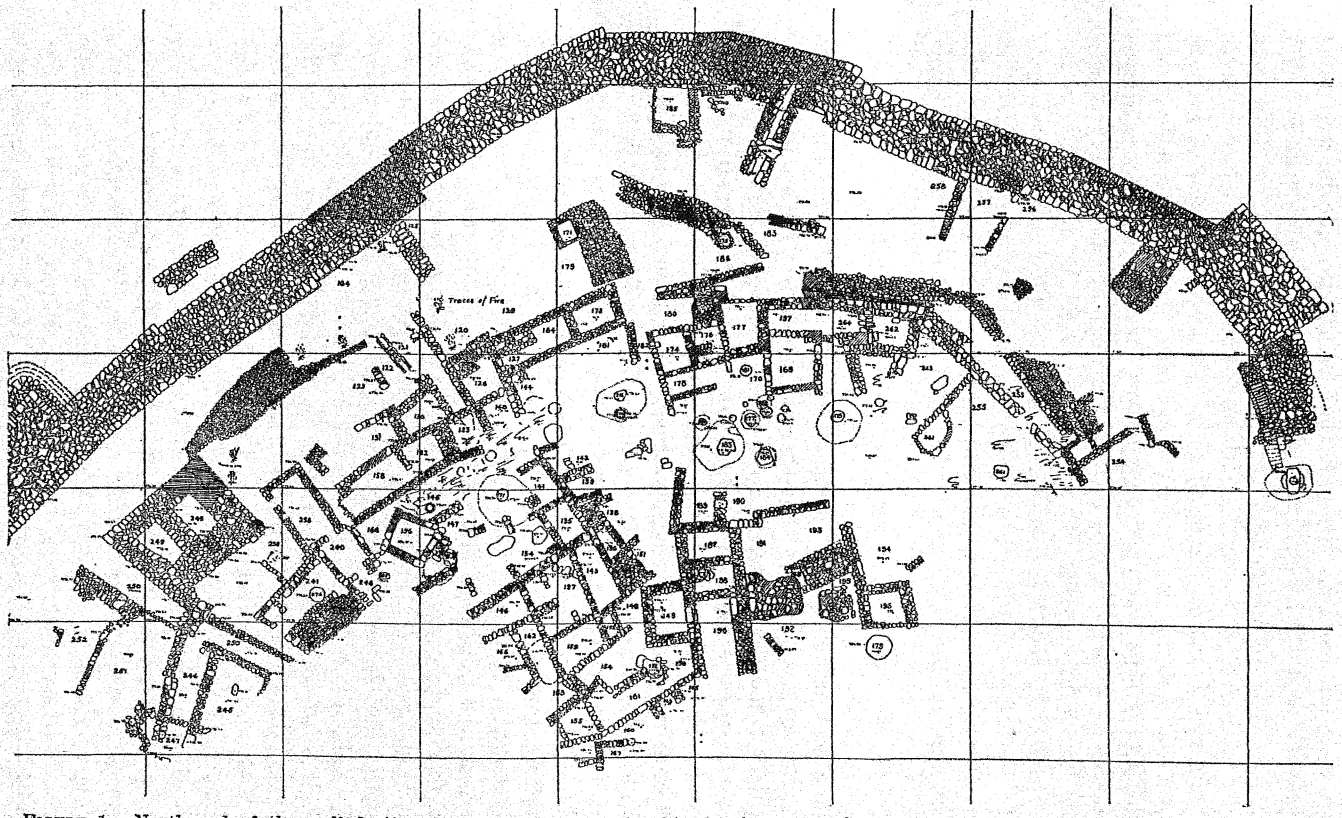



FIGURE 1.—North end of the walled city of Tell en-Nasbeh (Mizpah) showing map of a part of the structures excavated in 1929. The map shows chiefly the second level, Iron Age, 1200–800 B. C. The map is on a grid of 10-meter squares

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moat was subsequently found at two other widely separated points where we made sections through the extramural débris, and must be regarded as a well conceived part of the city's defences.

In the course of the summer we cleared a crescent of more than a hundred meters of the wall, with adjacent city areas, but no trace of a gate was found at the north end. However, in view of the size of the city, it seems certain that there must have been another gate besides the one at the south end. Two stretches of city wall still remain to be excavated, one on the west, the other on the east side of the Tell. Since, anciently, the north-south road passed on the west side of the Tell, the probabilities are in favor of a second gate on the west side. This is a problem that still awaits solution. One more season will enable us to complete the excavation of the entire mound and so find the answer for this as for a number of other questions.

## NEW FEATURES OF THE CITY WALL

The attack upon the Tell from the north end has had the advantage of revealing the fact that the city's defenses have had a more complicated history of construction than appeared from the earlier excavations at the south end. For instance, the inner and older city wall was not found at the north end, and hence no intramural area, filled in its upper level with grain bins. The main wall itself showed striking differences of construction. The builders had first excavated a wide trench, carried to bedrock, and this they filled to a height of 2 meters with loose rocks, mostly small. Upon this bed of rock fill the wall was built with courses of large stones, laid with clay mortar. The steady and increasing pressure of accumulating débris against the inner face of the city wall had gradually pushed it out so that, in spite of its great thickness, it began to lean outward more and more. This action was facilitated by the loose foundations and the absence of all counter pressure against the outer face of the wall, which coincided with the edge of the sharply descending rock slope of the hill. Ultimately it became necessary to save the wall from total collapse by building a buttress wall along the outside.

The structural peculiarities of this north-end wall made it necessary to ascertain, if possible, whether it was built at the same time as the Bronze Age wall at the south end. I had two sections cut through it, and the potsherds found in the masonry were carefully collected in baskets and labeled according to the successive courses of stones. There were numerous Early Bronze Age fragments, but a considerable proportion of the potsherds belonged to the Iron Age, a decisive indication that the wall, at the section points, could not have been built earlier than the Iron Age. The lowest course of the wall yielded only Early Bronze Age pottery, but this may have

been accidental, for there was no structural difference between the upper courses and the lowest. At the present stage of the excavations it seems probable that during the Bronze Age only the southern half of the Tell was inclosed by a wall, and that the northern end was included during the Iron Age. In that case we should expect a wall to bisect the Tell somewhere near the center.

### SUBURBS

One of the interesting results brought to light by the progress of this season's excavations is the fact that the ancient city extended considerably beyond the area included within the walls. There were what one might call suburbs which covered the comparatively broad, level terraces on the eastern and southern flanks of the Tell. The existence of an Iron Age suburb on the southern slope had been established during the excavations of previous years. During the season of 1929 I decided to cut a trench 20 meters wide from a point far outside the city wall directly up the eastern slope. Immediately beneath the tilled surface of the ground we found house foundations, silos, and cisterns with an abundance of first and second Iron Age pottery which coincided in fabric and forms with that found in the two upper levels on the Tell. Here there was evidence of a populous and prosperous city which occupied not only the top but also the flanks of the Tell during the Biblical period between the Judges and the Exile. As the trench was pushed into the talus of the final sharp slope of the Tell the workmen uncovered the mouth of a large cave. (Pl. 5.) Above it was a retaining wall, evidently of Israelite construction, for in its face were some squared stones not made for the use they now served. They had done earlier service somewhere in the upper courses of the main city wall. Beyond the rod-wide terrace of débris held in by the retaining wall, rose the city wall itself, based on rock, 16 feet thick, and well constructed.

### THE CAVE

When the cave was excavated its stratification furnished an epitome of the human history of the Tell. Occupation and use of the cave had ceased about 700 B. C., a period corresponding to the invasion of Sennacherib. Thereafter, apparently, débris began to accumulate over the opening. The upper layer of deposits, comparatively deep, contained all the characteristic forms of Iron Age pottery. Beneath this was a Middle Bronze Age stratum, and the lowest level, separated from the next above by a compact earthen floor, contained numerous fragmentary human remains mingled with Early Bronze Age pottery. There was no clearly recognizable Late Bronze Age stratum. In this respect the occupation levels of

the cave coincide with the stratification on the Tell where characteristic Late Bronze Age pottery is absent or represented sparingly. There is enough to indicate that further excavations may bring to light a Late Bronze Age occupation of the Tell.

In short, the evidence points to a first use of the cave by Early Bronze Age inhabitants of Palestine as a place of burial. Remains of 14 persons could be made out, but there may have been many more before the cave was cleared for occupation as a dwelling-place during the Middle Bronze Age. There is a suggestion of a sudden tragedy for the Early Bronze Age people in our discovery of a small kiln filled with pottery that had not been fired. It was at the entrance of the cave, and the pottery, made of a greenish clay, may have been intended for funerary purposes. Before the firing could take place an evil fate overtook the living and probably the dead. The Middle Bronze Age stratum of the cave contained many objects of great interest, among them a terra-cotta couch of a unique design.

## INTRAMURAL AREA

Above the cave, and within the city wall, our excavations connected with those of 1926. Here again we struck the two city walls, the outer and the inner, and in the space between them were numerous circular grain bins, like those found during the previous year. Along the inner wall ran a paved path over which purchasers and vendors, camels, and donkeys, came and went when this part of the city was a busy grain market. Thirty or forty meters farther north the inner circuit wall gradually turned westward away from the main wall, thus widening the intramural area. This wider space was at this point occupied by a moderately large square building, divided into four rooms, arranged exactly like those in the Israelite sanctuary discovered on the west side of the Tell in 1927. One room, about 8 by 30 feet, ran across the entire width of the building. Three others ran at right angles to it, and the central one was the largest. It contained a large circular-walled structure like a storage bin, about 2 meters in diameter, a stone basin, and a kind of table made of two flat stones. Among the objects found in the rooms were a terra-cotta dove, the torso of an Astarte figurine, and a small saucer lamp nested in the 3-branched fork of a tree, all in terra cotta. The lamp had been covered with white slip and then painted red, just like the Astarte figurines. Therefore it probably had religious significance and was of a votive character. The dove, as is well known, was a bird sacred to Astarte. So far as the evidence warrants a conclusion, we are concerned here with a sanctuary of Astarte, the "Queen of Heaven" (Jer. 44, 17). It may be added, as a significant fact, that in the immediate neighborhood of this

structure, heads of Astarte figurines were especially numerous, and a conical baetyl, or *maṣṣebah*, was also recovered in this vicinity.

### NATURE OF THE CITY LEVELS

So far as the levels within the city walls are concerned, this year's excavations gave us certainty on many points that were previously left in doubt. At the north end the uppermost level, not uniformly preserved, was Hellenistic, chiefly Maccabaean. Next came a stratum which yielded chiefly II, but also I, Iron Age pottery, especially in areas near the city wall. Sometimes there were two house levels in this stratum, the lower level having been partly reused in the upper. Sometimes this took the form of new floors within the same house walls. The lower, or Early Iron Age, level was always the best marked and indicated a long and continuous occupation of the city during that period. A considerable amount of so-called "Philistine" ware was recovered from this level. The third stratum must in the main be described as belonging to the Middle Bronze Age. But it had a large admixture of Early Bronze Age pottery, which may be regarded as intrusive. Remains of larger structures, kilns, and silos, had more successfully survived the digging activities of the Iron Age inhabitants. The final and lowest stratum, that of the Early Bronze Age, was in contact with bedrock. It had been much disturbed, and was found unmixed only in silos and natural cavities in bedrock. Large quantities of ledge handles were found in all the levels, but particularly in the lowest. So abundant in sheer bulk in this Early Bronze Age ware on Tell en-Nasbeh that we must assume for that period a long-continued and populous settlement on the hilltop.

### STUDY OF CERAMICS

During the season just closed we had an especially competent staff of 14 members, and consequently were able to give close attention to a number of special problems. Four members, trained in the study of Palestinian ceramics, gave particular attention to nearly 3,000 half-bushel baskets of potsherds that were brought down from the Tell. One member gave his whole time to the accurate labelling of the baskets, and the numbering of rooms, silos, cisterns, and other structures. After being brought down to headquarters the potsherds were washed, and examined in detail. Five by eight inch cards were used to make notes on the contents of each basket, and these were filed according to provenience for future reference or further study. In addition, all unusual forms, objects, or decorations were drawn to scale on 5 by 8 inch millimeter-ruled cards, and these were filed with the basket cards. In this manner over

2,820 object drawings were added to our files, besides the 768 which were recorded in our museum book.

### STAMPED JAR HANDLES

It was probably in part due to this systematic scrutiny of potsherds that we found during the past season a dozen or more jar handle seal inscriptions and graffiti on pottery. Two bear the name of the deity in the form of "Yah" or "Yahu." One bears the consonants MZH, probably referring to the feast of unleavened bread. These three seal impressions resemble similar ones found by Sellin and Watzinger at Jericho. Still another, very different from the last mentioned, bears the consonants MZP, and is, therefore, a companion piece of the MZP (Mizpah?) stamp found in 1927. There are a number of jar handle stamps with a flying eagle and the well-known legend "For the King. Hebron." On one impression which bears the simple legend "For the King" (le-Melek), the tail feathers are so clearly indicated that the stamp maker's intention to represent a bird and not a flying scroll can no longer be doubted. The graffiti are of some epigraphical importance on account of the forms of the Hebrew letters employed, but must be reserved for a separate discussion. Practically all the jar handle stamps were found in the II and I Iron Age levels. Unless a closer study of our detailed records of the ceramic context should oblige me to modify my present conclusions, these jar handle inscriptions belong to the period between 900 and 600 B. C.

### THE NECROPOLIS

The possible whereabouts of the Tell en-Nasbeh necropolis has for the writer been a subject of considerable thought during the past three years. There are numerous empty tombs in the rock terraces on the slopes of the Tell, but all of them appear, judged by their structure, to be isolated tombs of no great age. It seemed clear that for so populous a city there must have been a general burial place somewhere in the vicinity of the Tell. During the last month of the 1929 excavations I undertook a systematic search of the ridges and slopes contiguous to our city mound, and with most gratifying results. On the western slope of a ridge north of the Tell I observed in the slightly exposed bedrock what seemed to be the remains of a much weathered cutting. Removal of the accumulated débris soon brought to light a shallow forecourt, chiseled out of the limestone, and at its east end an upright doorstone was found still in place, rabbeted into the stone frame of a tomb entrance. Close to it, but on the north side of the sunken forecourt, was a smaller doorstone, fitted like a lid into the frame of another opening. (Pl. 6.)

It was evident that this was a tomb of considerable age. On removal of the larger doorstone the front of the tomb was found to be solidly filled with black earth carried in by seepage of water through ill-fitting joints in the doorway. When this earth had been removed it was found to be a tomb with a double history. The first burial, judging by the pottery, had been made about 700 B. C.; the second belonged to the Hellenistic period, about 250 B. C., or later. Only a part of the débris within the tomb, together with the skeletal remains, had been removed for the second burial, so that both deposits of funerary gifts were substantially preserved. The Hellenistic deposit comprised a number of vases and jars which were clearly imitations of Greek forms. One of them was an alabastron. There was also a small globular vase of fine thin paste, which is a remarkably faithful representation of a pomegranate. The prominent segmented calyx was made to serve as the neck of the vase, and even the scar made by tearing the fruit from the stem was faithfully imitated. A varied collection of jewelry, including rings, fibulae, brooches, and ear-rings, accompanied the ceramic deposit. (Pl. 7.)

The second and older deposit, dated provisionally near the beginning of the second phase of the Iron Age (800–586 B. C.), was represented by 30 pieces of pottery, among them 11 saucer lamps. Only one of them had a slight foot, a fact which, by comparison with lamps found in rooms and stratified deposits on the Tell, would tend to push back the date of this deposit to the close of the Iron Age I (1200–800 B. C.). The fact that only a few fragmentary human remains were found in the tomb may, as already suggested, be most plausibly explained by the supposition that at the time of the second burial the skeletons of the first burial were removed. The contents of the small tomb on the left side of the main entrance support this view. It seems originally to have been intended for the burial of an infant. Having been opened also at the time of the Hellenistic burial, and being found too small, some large bones of adults from the main tomb were thrust into it before it was closed again. In any case there were found in this niche some large bones of an adult lying on top of the very slight remains of a child burial. No other objects furnished any clue to its purpose or past history.

More difficult is it to account for the almost complete absence of skeletal remains in connection with the secondary Hellenistic burial, more especially since the door-stones were still in place. Perhaps the tomb was robbed a few years after burial. The smallness of the funerary deposit could then be accounted for on the assumption that the most valuable objects were removed together with the skeletons, or perhaps an ossuary containing the bones. The recovery of a small ornamental bronze handle of some receptacle which was no longer in the tomb, favors this explanation.

## TOMB NUMBER V

Feeling sure that there were other tombs in the immediate neighborhood, I had the thin cover of débris removed from the underlying rock, and soon we found the opening of another tomb close to the preceding. Its doorstone was gone. A flight of three stone steps led down from the small square opening into a central oblong pit flanked around the top by passages nearly a meter in width. At the back was another room whose floor had been sunk to the same depth as the pit in front. Both chambers were filled with earth to within a foot of the ceiling. When cleared this tomb was found to contain an astonishing amount of pottery of the Early Iron Age (1200–800 B. C.) and is, therefore, contemporaneous with the earlier period of Old Testament history. Two scarabs, found with the pottery, will be submitted to expert Egyptologists, for they may furnish a more definite date for the burial deposit.

The tomb has yielded 183 museum objects, besides much other material for historical study. One curious terra-cotta bottle jar, so far as known, is unique. It simulates, with incised spirals, a beehive built up in a blunt cone by means of coiled ropes of straw. A spirally incised bottle neck on the side makes the doorway for the bees. Inside of the jar was found a waxlike deposit which, on chemical examination, may confirm the plausible supposition that it was used to provide a food offering of honey for the dead. (Deut. 26 : 14.)

Another piece of pottery suggests a swan. The long curved neck is surmounted by a pitcher mouth with laterally pinched lips simulating a mandible. On top, or in other words on the back, are painted in red and black bands the outlines of wings. This object may have come from Cyprus or may be a local imitation of Cypriote art. Among the scores of other vessels are amphoras, bottle jugs, pitchers, saucers, chalices, an incense burner, and other forms hard to describe. There were scores of small black juglets which probably contained oil or some other substance deemed important to the dead. Equally numerous were the saucer lamps, and not one of them had even the suggestion of a foot. Among 30 bowls of various sizes and forms there were some that had been pebble burnished over a deep red slip.

After clearing these two tombs I once more examined the surroundings on the slope where they were situated, and became fully convinced that we had found the Tell en-Nasbeh necropolis, the city of the dead. The only question on which we needed further light was the length of the historical period during which burials had been made here. The two tombs already cleared covered the period from the Early Iron Age to the Hellenistic period, 1200 to 250 B. C. Was the slope also used for burials during the Bronze Age? Not

more than 40 feet away from the above-mentioned tombs I found on the surface a fragment of a ledge handle which seemed to answer my question affirmatively.

## LAST HOUR DISCOVERIES

To gain, if possible, more certainty on this point, I directed an Egyptian foreman and two local workmen to sink a shaft where the telltale ledge handle fragment was found, and before long we had other ledge handles and a basketful of Early Bronze Age ware of the kind found in our deepest level on the Tell. The excavation soon opened the broken-down remains of a typical Early Bronze Age cave tomb, and a passage leading away from it into bedrock beyond, may be the approach to one that is still undisturbed. But we were too close to the date agreed upon with the department of antiquities for the division of the season's finds to risk the opening of another tomb. Our whole staff, working at the utmost pressure, could scarcely hope to complete, in the time remaining, the drawing, photographing, and recording of the objects which already covered all our tables and shelves at headquarters. So I reluctantly gave directions to wall up the underground passage and fill up the shaft in expectation of a time when we may return to delve still further into the historical secrets of that rocky and weather-beaten hillside.

The same pressure for time and space compelled us to halt on the brink of interesting revelations in the excavations on the Tell itself. At the farthest edge of the last strip excavated, we opened on the inner edge of the city wall a vaulted passage and a long flight of stone steps leading down into—what? Around the entrance were house foundations of the Maccabaean period, and house walls running out upon the city wall during a long time after the last walled city had ceased to exist. Two Hellenistic lamps and a coin found in the descending passage suggest that the Maccabees were its builders, and certainly the last who used it. When fully excavated it was found to end in an underground cave or grotto. In the center was the mouth of a rock-hewn cistern carefully covered with flat stones, a bit of thoughtfulness which shows that those who did it had no expectation of leaving it forever as they walked up the long flight of steps 2,000 years ago.

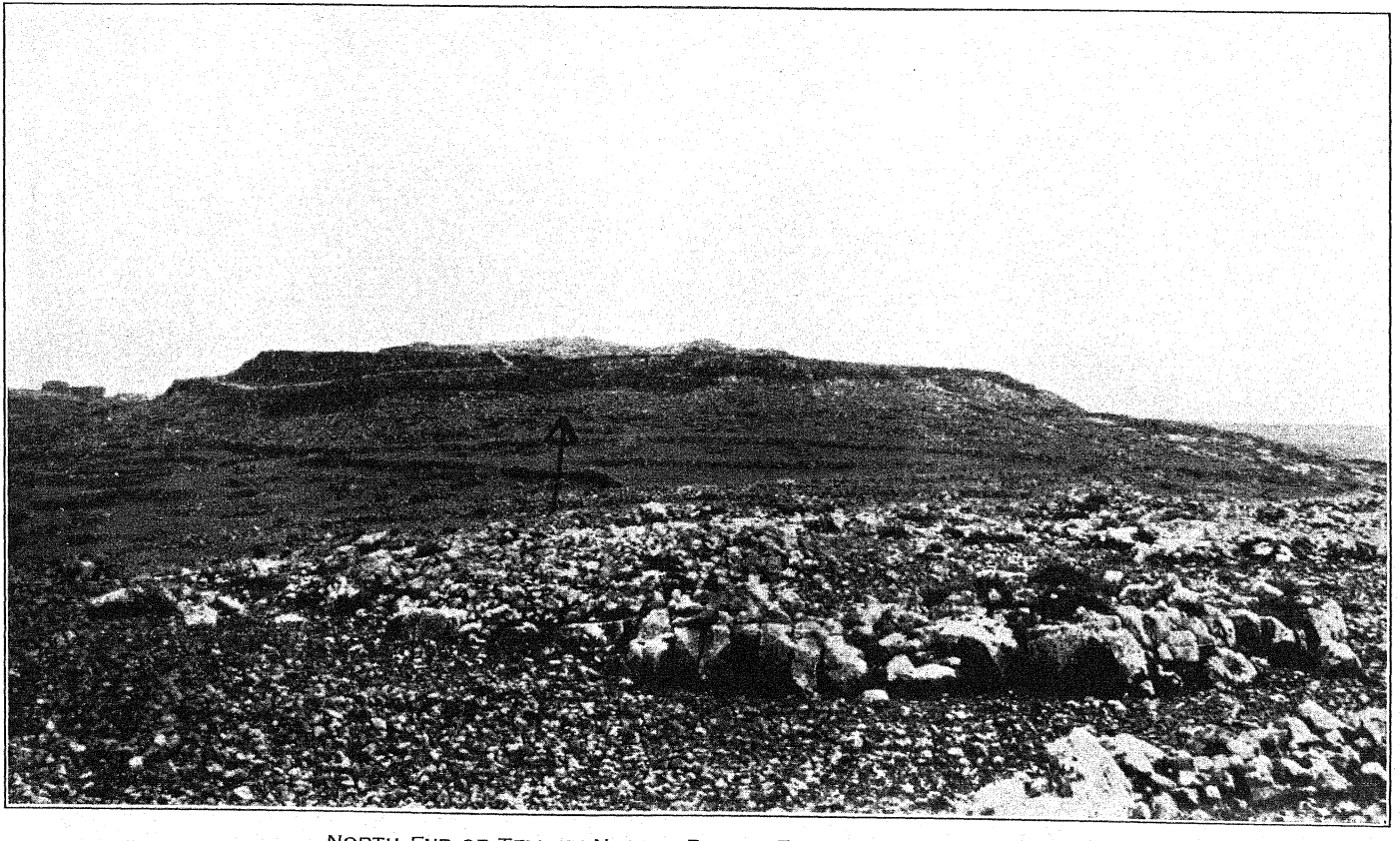
A peep into the depths of the cistern showed a small cone of loose débris rising above the washed-in sediment at the bottom. Its connection with the Maccabaean level, and the fact of its being underground, made me eager to excavate the cistern. A week might have sufficed to extract and record the secrets of its past. But we had no week to spare. So we had to content ourselves with photographs and drawings of the externals. Under my direction the

workmen then built a wall across the passage to the grotto and spread a deep blanket of earth over the top.

### A GRAECO-ROMAN TOMB

In conclusion, we must recur once more to what we shall now call the North Cemetery. In the immediate vicinity of the Iron Age Tombs III and V, I had observed partly collapsed and weathered-out tombs, whose surface appearance indicated that they belonged to the Hellenistic or even to a later period. One of these, the best preserved, had a covered forecourt about 6 feet square, and not quite 6 feet high. It had been hewn from a ledge of limestone. The whole of the west side was open to the weather. The smooth vertical wall of the east end was pierced at the floor level by a small square opening scarcely large enough to admit a man. Both the forecourt and the entrance were choked with rocks and soil to such an extent that no animal larger than a fox could have entered the tomb. After this had been cleared away, it could be seen that the tomb itself was filled with débris nearly to the top.

On consulting the Arab owner of the land on which the tomb was located, he told me that it had been opened by an Arab purveyor of antiquities just before the war, that he employed only one assistant, and that he felt sure the tomb had not been entirely cleared. It was, indeed, still largely filled with washed-in débris. Desiring to ascertain, if possible, the age of the tomb, I directed one of our Egyptian gang leaders to clear it and two women carriers to sift the materials for small objects. We were not disappointed. Very soon a coin of Herod Archelaus came to light. This Archelaus, who ruled from 4 B. C. to 6 A. D., is the one mentioned in Matthew 2:22. He was a cruel ruler, and committed many outrages upon the Jews. The latter denounced him so bitterly at Rome that he was cited by the Emperor Augustus to appear before him. Unable to justify himself, he was banished to Vienna in Gaul in the year 6 A. D. The tomb, therefore, belongs approximately to the beginning of the Christian era. Remains of beads, jewelry, seals, lamps, and other objects recovered are also appropriate to this period, and are of special historical interest, on account of their chronological coincidence with the boyhood of Jesus of Nazareth.



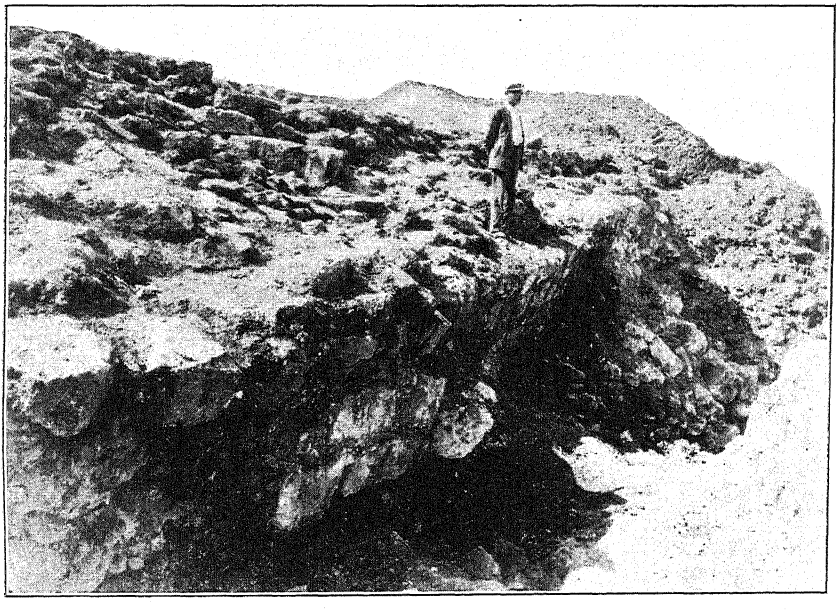
NORTH END OF TELL EN-NASBEH BEFORE EXCAVATION, MARCH, 1929



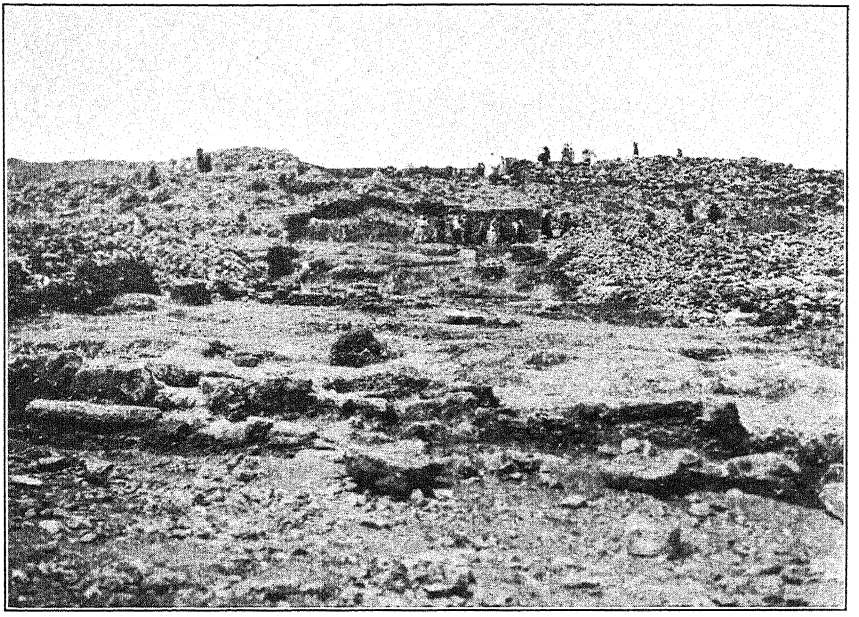
MASONRY OF CITY WALL AT THE SOUTH END, OUTER FACE; THICKNESS 20 FEET



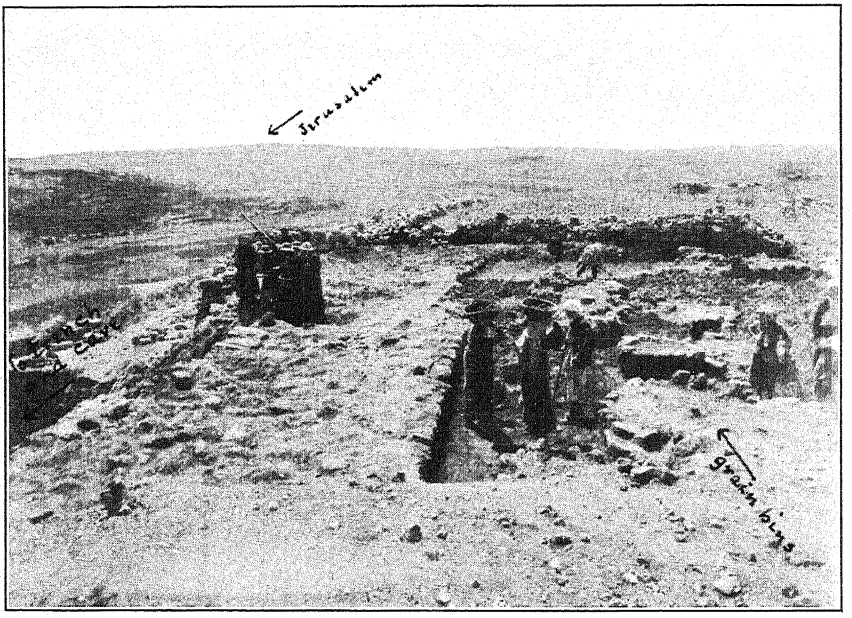

1. TOP OF CITY WALL EMERGING AT THE NORTH END



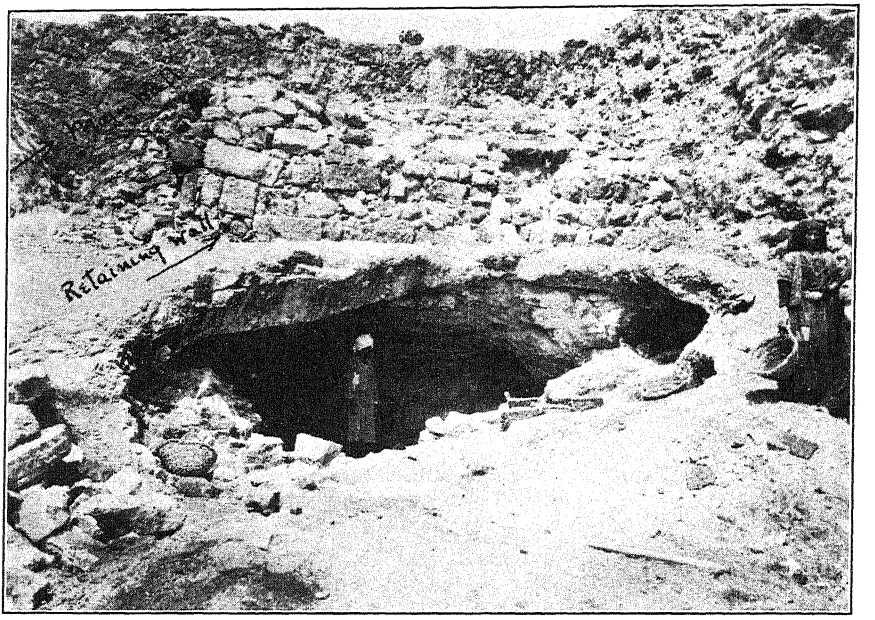
2. LEANING OUTER FACE OF NORTH WALL, PARTLY EXCAVATED



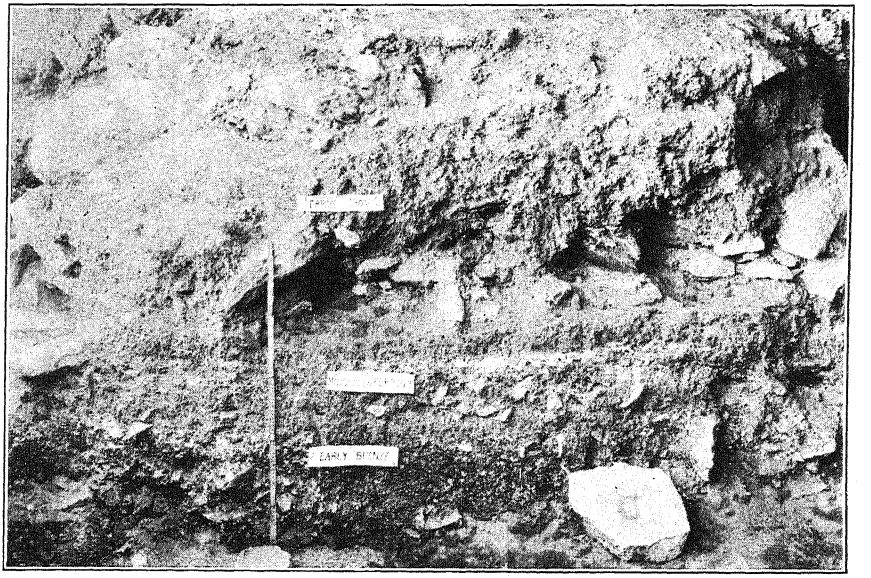
1. CUTTING THE TRENCH UP THE EAST SLOPE. FIRST AND SECOND IRON AGE HOUSE FOUNDATIONS IN THE FOREGROUND



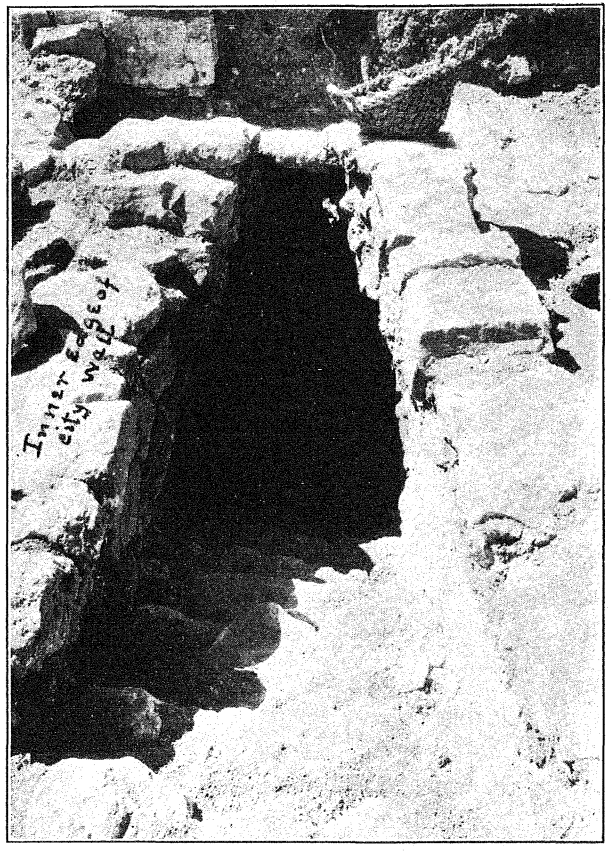

2. TOP OF CITY WALL ABOVE THE TRENCH AND CAVE ON THE EASTERN SLOPE



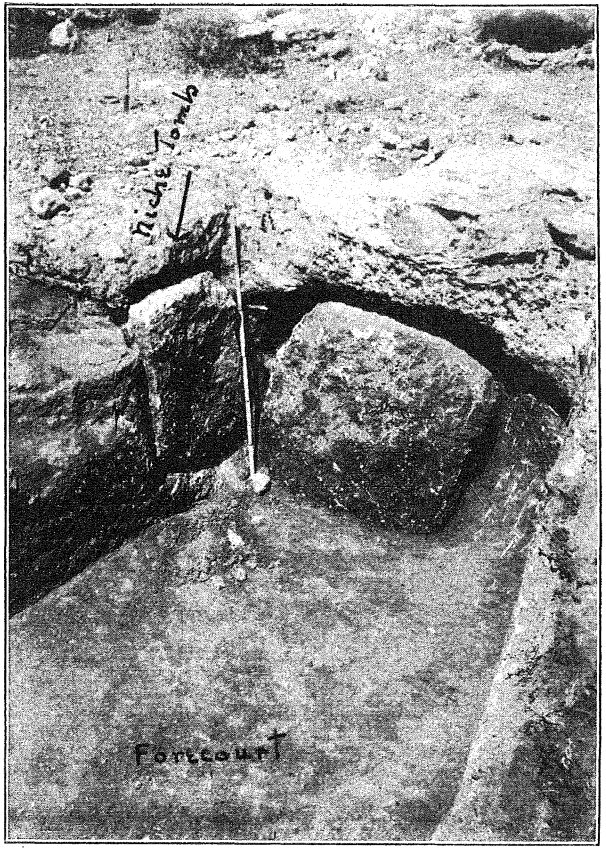

1. CAVE ON THE EAST SLOPE; ABOVE IS A SECTION OF IRON AGE RETAINING WALL AND BEYOND IT THE MAIN WALL ITSELF



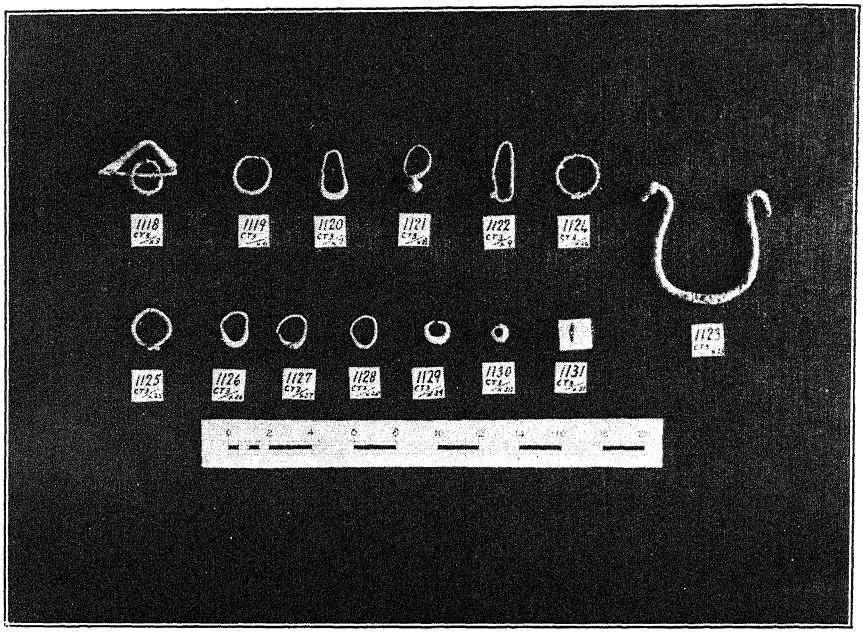
2. STRATIFICATION IN THE CAVE ON THE EAST SLOPE



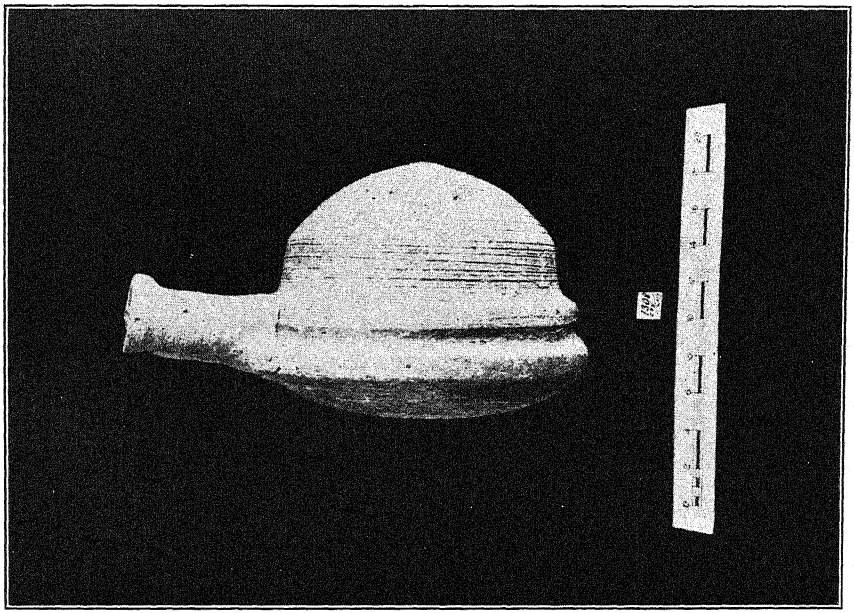

1. CORBEL-VAULTED PASSAGE LEADING TO A GROTTO IN THE NATURAL ROCK WITH THE MOUTH OF A CISTERN IN THE CENTER. SEE P. 493



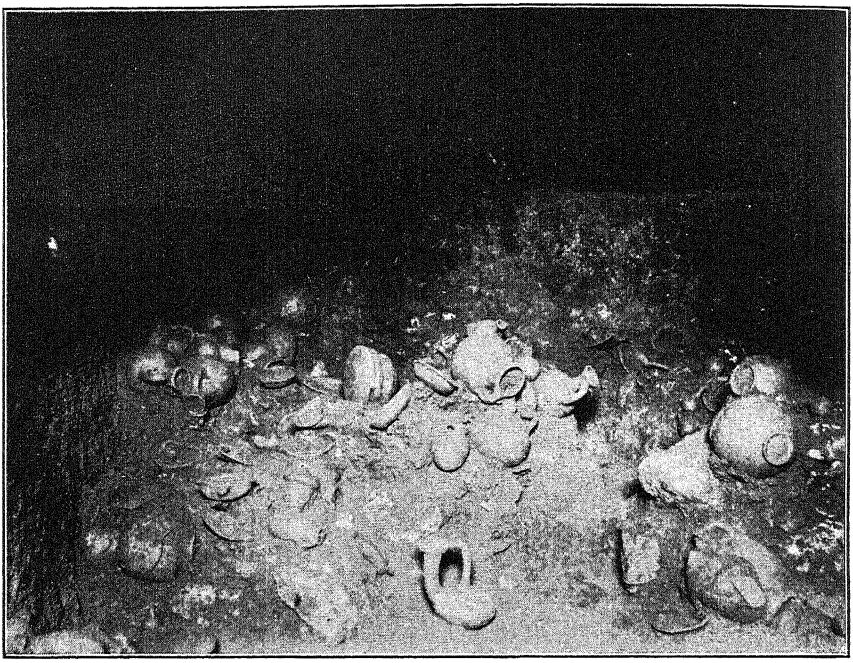

2. TOMB 3, AS FOUND, BEFORE OPENING



1. COLLECTION OF SILVER AND BRONZE JEWELRY FROM TOMB 3



2. BEEHIVE JAR FROM TOMB 5



1. INTERIOR VIEW OF MAIN CHAMBER OF TOMB 5 WITH POTTERY IN SITU




2. EXCAVATING INTRAMURAL AREA UNDER GRAIN BIN LEVEL. STONE MARKED + IS IN THE WALL OF THE ASTARTE SANCTUARY. SEE P. 488

# RECENT PROGRESS IN THE FIELD OF OLD WORLD PREHISTORY[1]

By GEORGE GRANT MACCURDY

[With 8 plates]

A little more than a year ago, geologists and glaciologists were celebrating the one hundredth anniversary of the birth of glaciology as a science. The year 1930 might well be chosen as the one hundredth anniversary of the birth of prehistory as a science, since it was in 1830 that Thomsen of Copenhagen applied his new system of prehistoric chronology to the Danish National Museum collections. There is something back of the fact that these anniversaries come so nearly coinciding. Progress in glaciology has meant much toward progress in prehistory. Chronologically speaking, the Ice Age falls within the limits of prehistoric time and the precision of our knowledge concerning glacial and interglacial chronology helps us to date many of the prehistoric relics inseparably linked with Ice Age deposits and fauna. In the past few years, much progress has been made in this field of research. In our summary then of recent progress in Old World prehistory let us first see what has been done in the way of correlating Ice Age with prehistoric chronology.

*Correlation of Ice Age and prehistoric chronology.*—For years the general consensus of opinion was that the last phase of Mousterian culture was coincident with the advance of the Würm or last glaciation and that Upper Paleolithic (Aurignacian, Solutrean, and Magdalenian) was coincident with a part of the maximum Würm glaciation and the major part of its retreat. Until very recently conservative prehistorians attempted to compress practically all of the Lower Paleolithic into the last interglacial epoch (Riss-Würm). In 1912, Commont had come to the conclusion that at least an early phase of the Chellean (Pre-Chellean) should be placed in the next to the last (Mindel-Riss) interglacial.

The recent progress in this direction is due largely to J. Reid Moir and the Abbé H. Breuil. The main points in Breuil's syn-

[1] Reprinted by permission, with author's revision and addition of illustrations, from Proceedings of the American Philosophical Society, vol. 69, No. 4, 1930.

chronism of European glaciations and European cultural epochs, slightly modified, may be tabulated as follows:

| Glacial and interglacial stages | Cultural stages | | |
|---|---|---|---|
| Post-Würm | | | Tardenoisian<br>Azilian<br>Final Magdalenian |
| Würm II | | | Lower Magdalenian<br>Solutrean |
| Laufen Retreat | | | Aurignacian<br>Final Mousterian |
| Würm I | Levalloisian V | | Mousterian |
| Riss-Würm Interglacial | Levalloisian III–V<br>Micoquean | | Early Mousterian<br>Grimaldi phase<br>Weimar phase |
| Riss | Derived and worn specimens of earlier cultures | | |
| Mindel-Riss Interglacial | Upper Acheulian<br>Middle Acheulian<br>Lower Acheulian | Levalloisian II<br>Levalloisian I<br>Micoquean | Clactonian |
| Mindel | Derived and worn specimens of earlier cultures | | |
| Günz-Mindel Interglacial | Chellean<br>Pre-Chellean | Early Micoquean | Base of Clactonian |
| Günz<br>Pre-Günz | Sub-Crag industry | | Eolithic of some authors |

*Egypt.*—A fairly complete story of the Stone Age in Egypt is slowly taking shape due to the researches of Miss G. Caton-Thompson and Miss E. W. Gardner and more recently to those undertaken by the Oriental Institute, University of Chicago, with K. S. Sandford and W. J. Arkell in charge.

The Study of Nile-Faiyum Divide during Pliocene and Pleistocene Times by Sandford and Arkell appeared in 1929 as Volume X of the Oriental Institute Publications.[2]

In Upper Egypt they have identified a series of four river terraces in which Lower and Middle Paleolithic implements occur in situ as follows:

| Height above Nile | Cultures |
|---|---|
| 3 meters (10 feet) | Mousterian. |
| 9 meters (30 feet) | Early Mousterian. |
| 15 meters (50 feet) | Acheulian. |
| 30 meters (100 feet) | Chellean. |

[2] Vol. I of Prehistoric Survey of Egypt and Western Asia.

These have been traced over some hunderds of miles on both sides of the Nile and in adjoining deserts between Assuan and Assiut.

In Lower Egypt, between the Faiyum and Cairo, the series is not so complete. Thus far no representative of the 30-meter terrace has been discovered, but an old Nile channel at an elevation of 26–21 meters has yielded waterworn (derived) Chellean and fresh Acheulian implements. The Mousterian terrace in Lower Egypt has been traced through the Hawara Channel and into the Faiyum. The evidence shows that in Mousterian times the Faiyum was occupied by a vast lake fed by the Nile.

The Faiyum Basin is an integral part of the Nile system; not a tributary system as once supposed, but an overflow reservoir into which the Nile discharged its surplus water. In Paleolithic times this Faiyum lake was full. The surface of the lake then stood at 34.2 m. (112 feet) above sea level. There was an annual flood and annual low Nile in Paleolithic times as there is to-day. Now the annual Nile flood reaches Cairo in late summer. Thus it may have been the early autumnal gales that swept from the west across the Faiyum Lake, then at high level, which produced the storm beach some 10 feet (3.05 m.) high along the eastern shore of the lake. Strong westerly autumnal gales still sweep across the Faiyum Basin; but on the shores of the shrunken survivor of the old lake now hidden far below sea level, they produce a storm beach barely a foot high (30 cm.).

Along the eastern shore of the old Faiyum Lake a short distance south of the Philadelphia ruins, there are important implement-bearing deposits. The site is at Gebel er-Rus, the implements are of Mousterian age and the elevation is 34 m. (115.5 feet) above sea level. The richest site thus far discovered in the Faiyum is on the beach at Ḳasr Basil near Tutun on the southern shore of the old lake and at an elevation of 34.2 m. (112 feet). There is a basal pebble bed with Mousterian implements on which is superposed a silt deposit in turn covered by gravel, both containing Mousterian implements. The cores or nuclei as well as the finished tools resemble those found in Mousterian stations of western Europe. The cores vary from elongated to squarish ("double-ended") and discoid forms. The material employed was of flint or chert.

In the kitchen middens and the silts associated with them in the Kom Ombo plain, between Edfu and Assuan, E. Vignard has found an industry which seems to have evolved locally from the Mousterian, but which in time ceased to be recognizable as Mousterian, owing to an accumulation of modifications and the growth of new types. To the modified indigenous industry Vignard has given the name Sebilian. He divides it into three phases: Sebilian I, II, and III. The Mousterian disk persists in Sebilian I. The microlithic flakes and

implements of geometric design in Sebilian III are comparable in technique with the Tardenoisian industry and may be of the same age.

Sandford and Arkell find that the Sebilian industry described by Vignard is not confined to the Kom Ombo plain. They find it on both sides of the Hawara Channel, especially at Kon Medinet, Ghurab and Dimishḳin, in silt and fine gravel. Within the Faiyum, the gravel banks flanking the Hawara Channel spread out into a second system of beaches, storm beaches and shoals closely resembling those associated with the lake of Mousterian times. The water in the lake during the Late Paleolithic or Sebilian times stood at 28 m. (92 feet) above sea level, or 6.1 m. (20 feet) below its elevation in Mousterian times. An exceptionally prolific Sebilian site was found on the shore of this late Paleolithic lake near Philadelphia. The beach of this old lake is a prominent feature in the great bay of Philadelphia and the greater part of the Greco-Roman town was built upon and just behind it. In an obscure corner of the Faiyum Basin between Shaḳluf Bridge and Ḳasr Basil, Sandford and Arkell were so fortunate as to find no less than 10 beaches left by the falling lake as the climate became progressively more arid.

The industry of Late Paleolithic or Sebilian age found at the 28 m. (92 feet) beach level is of surprising uniformity. The cores are miniatures of the Mousterian cores. The flakes fall into two classes: (*a*) Miniatures of the Mousterian flake and (*b*) thin broad flakes with straight parallel margins. Most of the microlithic Sebilian types of Upper Egypt still remain to be discovered in Lower Egypt.

The field work of Sanford and Arkell terminated with the 22.5 m. (74 feet) level. However they agree with Miss G. Caton-Thompson and Miss E. W. Gardner that the 22.5 m. (74 feet) lake was succeeded by a Neolithic lake at a level of 17.4 m. (57 feet); that these two successive lakes were separated by a long interval of time, during which the Faiyum Basin was drained and the old lake deposits were deeply eroded before the water rose again to the 17.4 m. (57 feet) level, decadent Neolithic industries being associated with it down to 2.1 m. (7 feet) below sea level; that it has since continued to sink until the present day, when its surface lies 44.8 m. (147 feet) below sea level and only 5.5 m. (18 feet) above the bottom of the deepest part; that the last stage of contraction has been accompanied by a sudden increase in salinity, which has killed most of the freshwater fauna, two marine bivalves taking its place. Desert conditions were apparently established in Upper Egypt as early as Sebilian times, and at a later date as one proceeds northward, north of the latitude of the Faiyum, they may not have become absolute until post-Neolithic times.

*Mesopotamia.*—There is every reason to believe that records similar to those reported from the Upper Nile Valley will be found in the upper stretches of the Euphrates and Tigris Valleys. In fact, Passemard has reported the finding of a Chellean hand ax from the gravels at the base of the 30-meter terrace, right bank of the Euphrates between Rakka and Deir ez Zor, Syria. In type and patina it is exactly like those found in the Thames Valley at Milton Street and in the Somme Valley. Passemard also points out that in the Euphrates Valley one finds a system of terraces at four levels—15, 30, 60, and 100 meters respectively—comparable with the four terraces to be found in the river valleys of western Europe.

*France.*—Even older than the Chellean of the 30-meter terraces in the valleys of the Nile and the Euphrates are the crude artifacts found by Peyrony only last summer in the basal deposits of the station known as La Micoque, near Les Eyzies (Dordogne). The site has been known for at least 35 years, beginning with the excavations of Chauvet and Rivière. Many prehistorians have since done at least some work on this spot. All were agreed as to the relatively great antiquity of the deposits, dating back at least to the Acheulian Epoch. Each stopped at a thick sterile deposit supposed to underlie the oldest relic-bearing level. It remained for Peyrony to hazard a sounding deeper than all the others. He was rewarded by finding a basal relic-bearing deposit far below the lowest hitherto known. The artifacts are eolithic in type and are referred by Peyrony to the Pre-Chellean Epoch (Lower Pleistocene). Peyrony has also just added another page to our knowledge of another site in the Dordogne—the type station of Le Moustier. The oldest relic-bearing level hitherto known at Le Moustier belongs to the Mousterian Epoch. Beneath this is a thick sterile deposit beneath which Peyrony has found an additional relic-bearing deposit. But the cultural remains are of a type similar to those in the level above. Peyrony's successful soundings at La Micoque and Le Moustier should serve as a reminder to all excavators to be sure they are at the bottom of a section as soon as possible after their work is begun.

By combining four rock shelters in the Dordogne—La Micoque, Le Moustier, Laugerie-Haute, and Laugerie-Basse—it is now possible to build up a composite section representing the entire gamut of Stone Age cultures from the pre-Chellean to the Neolithic, inclusive.

*Chou Kou Tien.*—The year 1929 will compare favorably with any single year, in the past one hundred, in respect to prehistoric achievement. The discovery of an almost complete skull of an early type of man at Chou Kou Tien southwest of Peiping (Peking), China, is perhaps the outstanding event of the year (pls. 1–3). The first discovery of hominid remains at Chou Kou Tien was some four years ago.

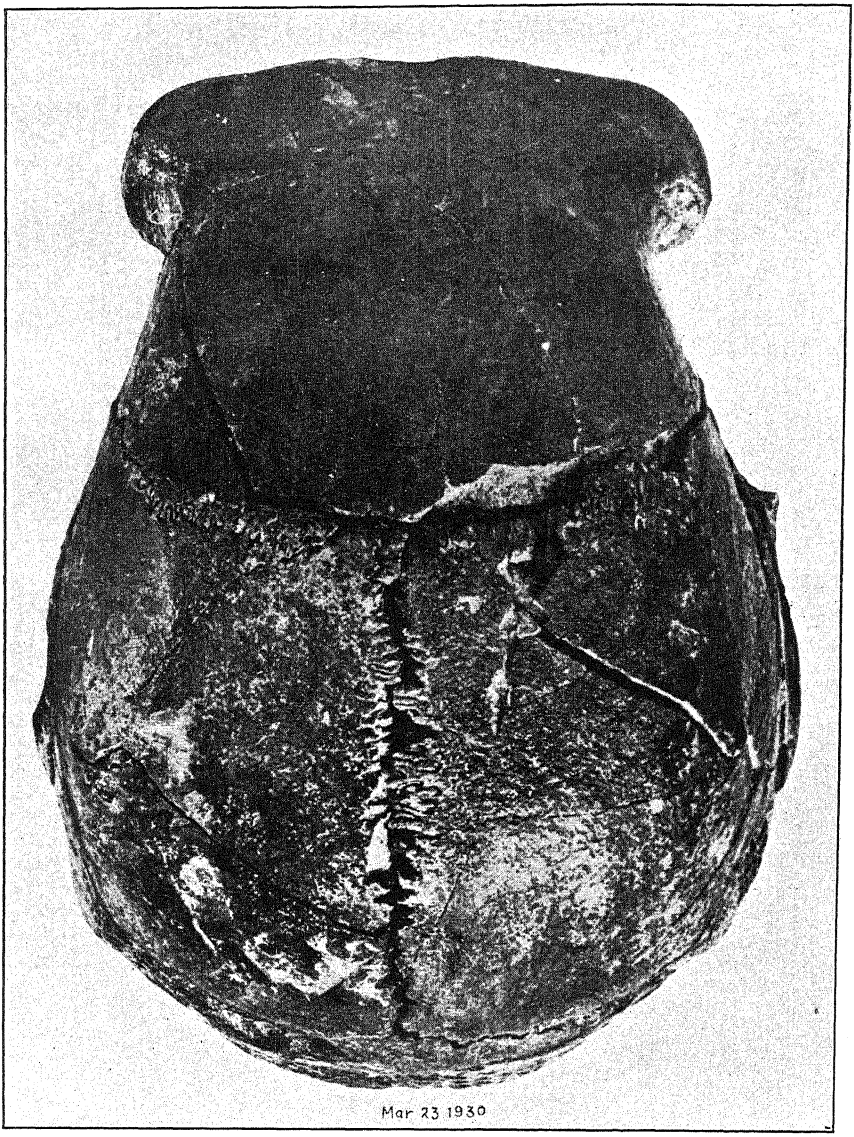
From 1923 to 1926 there were recovered two human teeth from material that had been previously taken from the Chou Kou Tien deposit—a right upper molar and a lower first premolar. In October of the following year Doctor Bohlin found a left lower permanent molar (probably the first) of a child.

During the season of 1928 there were found in the same deposit (Locus A) the right horizontal ramus of an adult human lower jaw with three molar teeth in situ and leaving the premolar, canine, and distal half of the lateral incisor sockets preserved; a somewhat worn right upper molar (M 1 or M 2) showing definite evidence of injury during life; the labial side of the crown and portion of the root of a permanent upper median incisor and immature lower (?) permanent incisor; and lastly the labial half of the crown and root of a worn lower median permanent incisor, posthumously crushed and deformed. The specimens are deeply pigmented and mineralized in a manner characteristic of all fossils recovered from locus A.

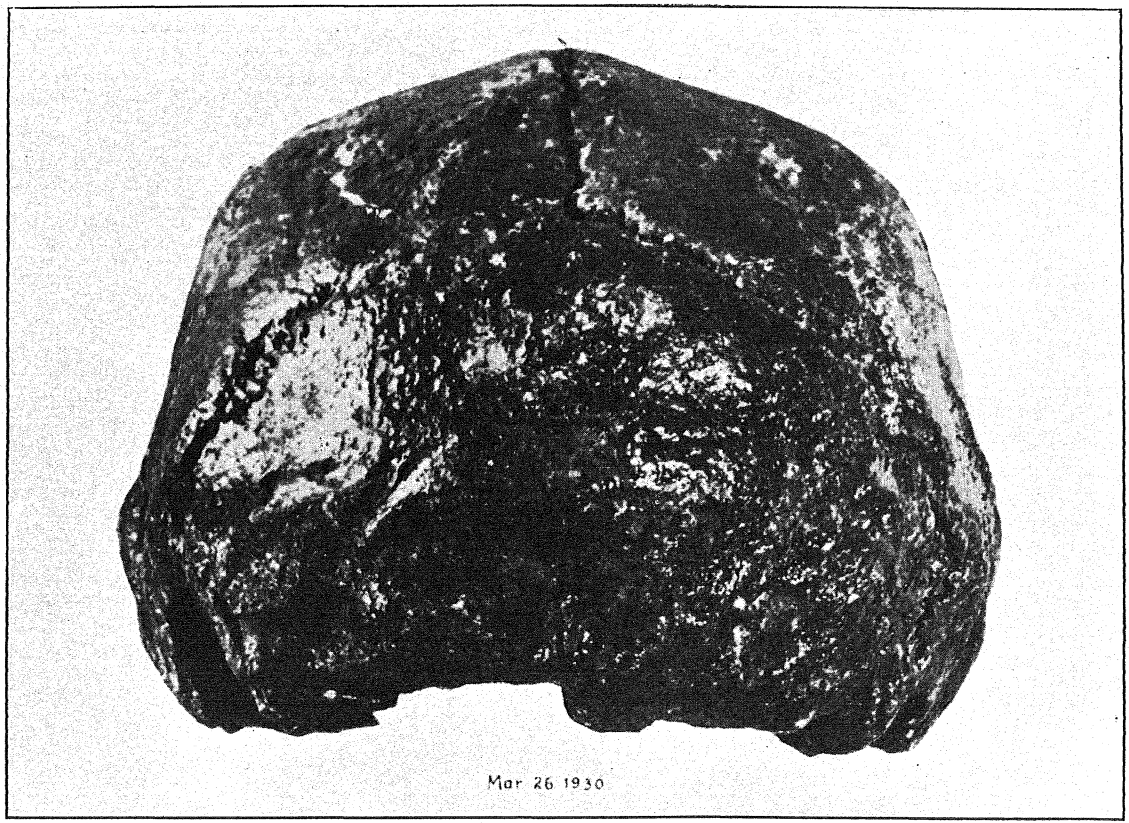
The fossils from Locus B of the same Chou Kou Tien deposit are not deeply pigmented, most of them being quite white or of light buff color. They are imbedded in a hard yellowish travertine. Not much of the hominid material has as yet been disengaged from the travertine matrix, enough, however, to prove that the hominid material from both loci belong to the same genus and species, to which Dr. Davidson Black has given the name *Sinanthropus pekinensis*. The specimens thus far disengaged include a score or more of both deciduous and permanent teeth representing many phases of wear and age, together with complete symphysis region of the lower jaw of a very young individual; other specimens are already visible in the matrix.

In December, 1929, while excavating a sheltered recess of the main deposit at Chou Kou Tien, Mr. W. C. Pei discovered the greater part of an adult hominid cranium in a good state of preservation (not even crushed). Within the main cave deposit at Chou Kou Tien up to the present time *Sinanthropus* remains have been recovered from five different loci, three of which, including the last major find, have been discovered by Mr. Pei during the last season's work. Contrary to any reports which have been circulated, no skeletal parts other than the skull and numerous isolated teeth have been recovered during the past year's excavations.

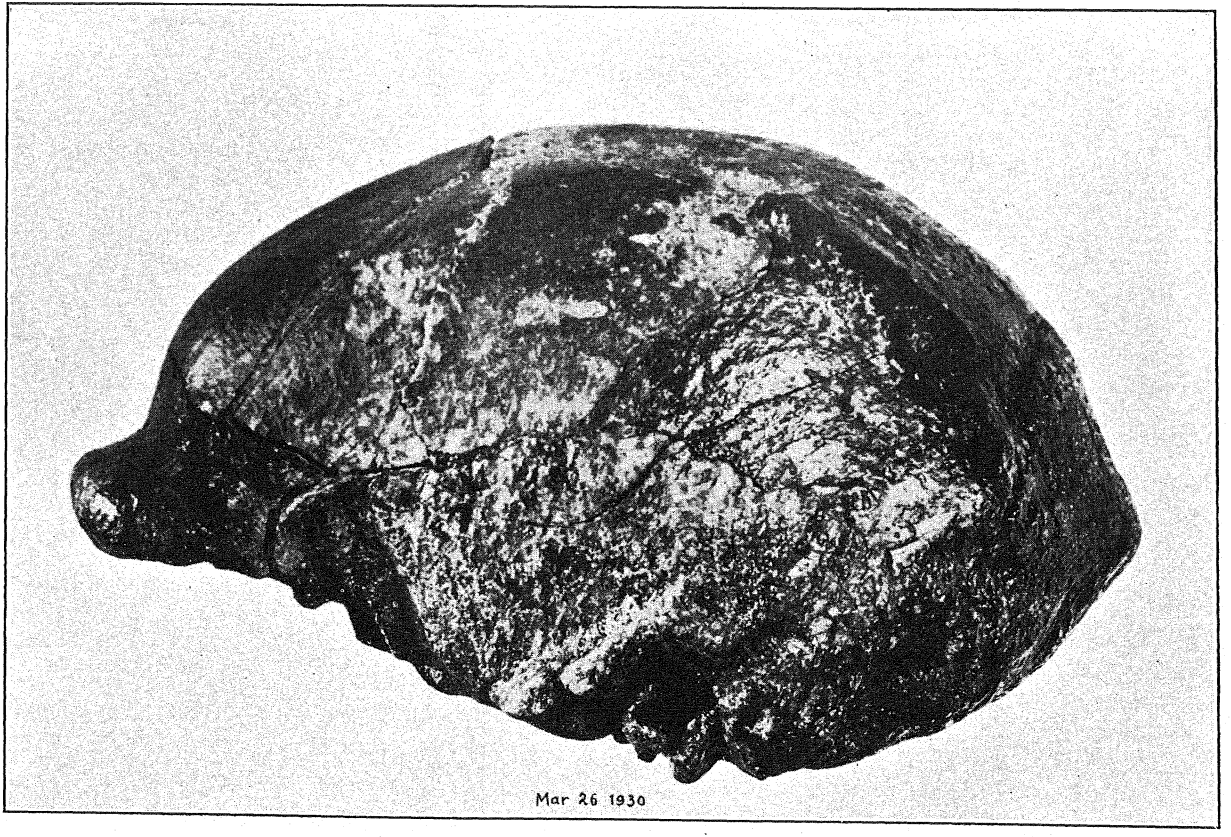
It should be noted that the different *Sinanthropus* loci discovered within the main Chou Kou Tien deposit are all clearly contemporaneous with one another, being Lower Quaternary (Polycene) in age. This latter statement is based on the evidence collected in a preliminary report on the geology and paleontology of the site by



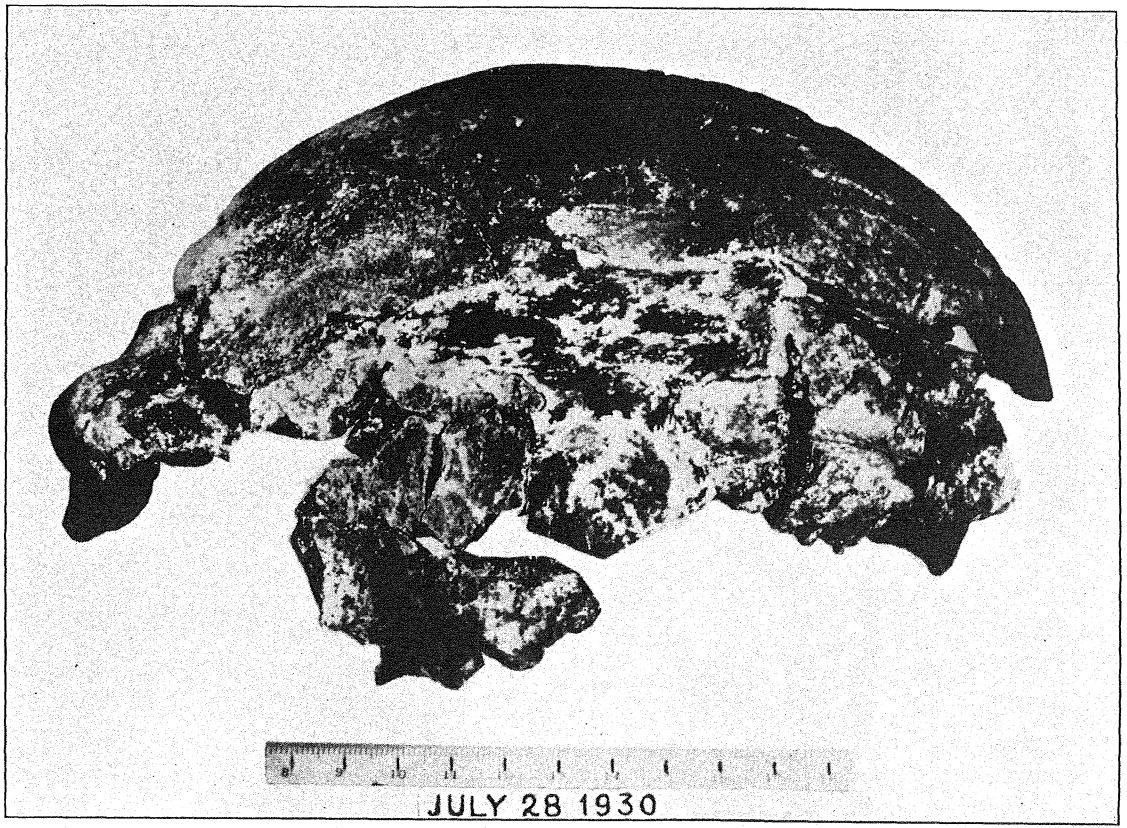

SINANTHROPUS PEKINENSIS



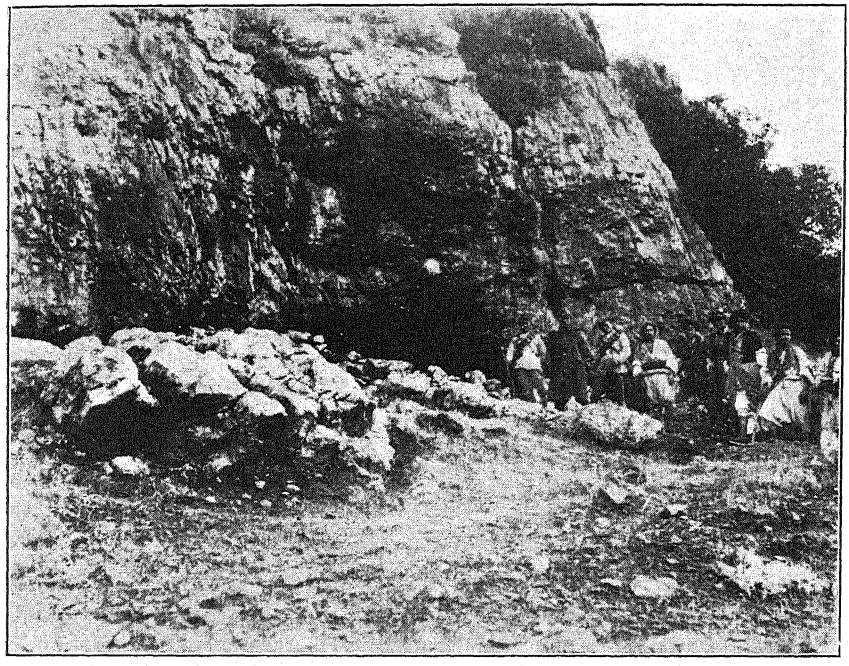

SINANTHROPUS PEKINENSIS



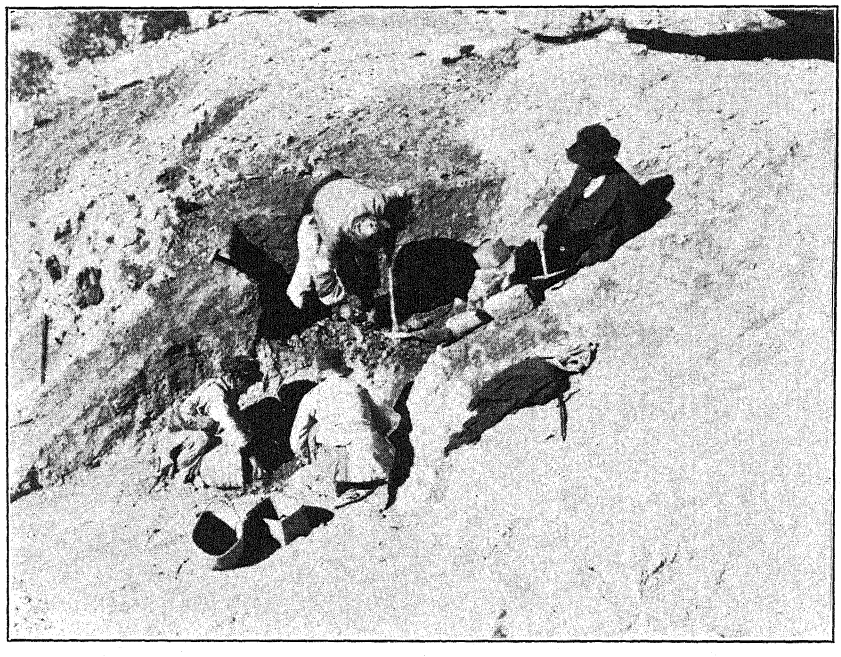

SINANTHROPUS PEKINENSIS



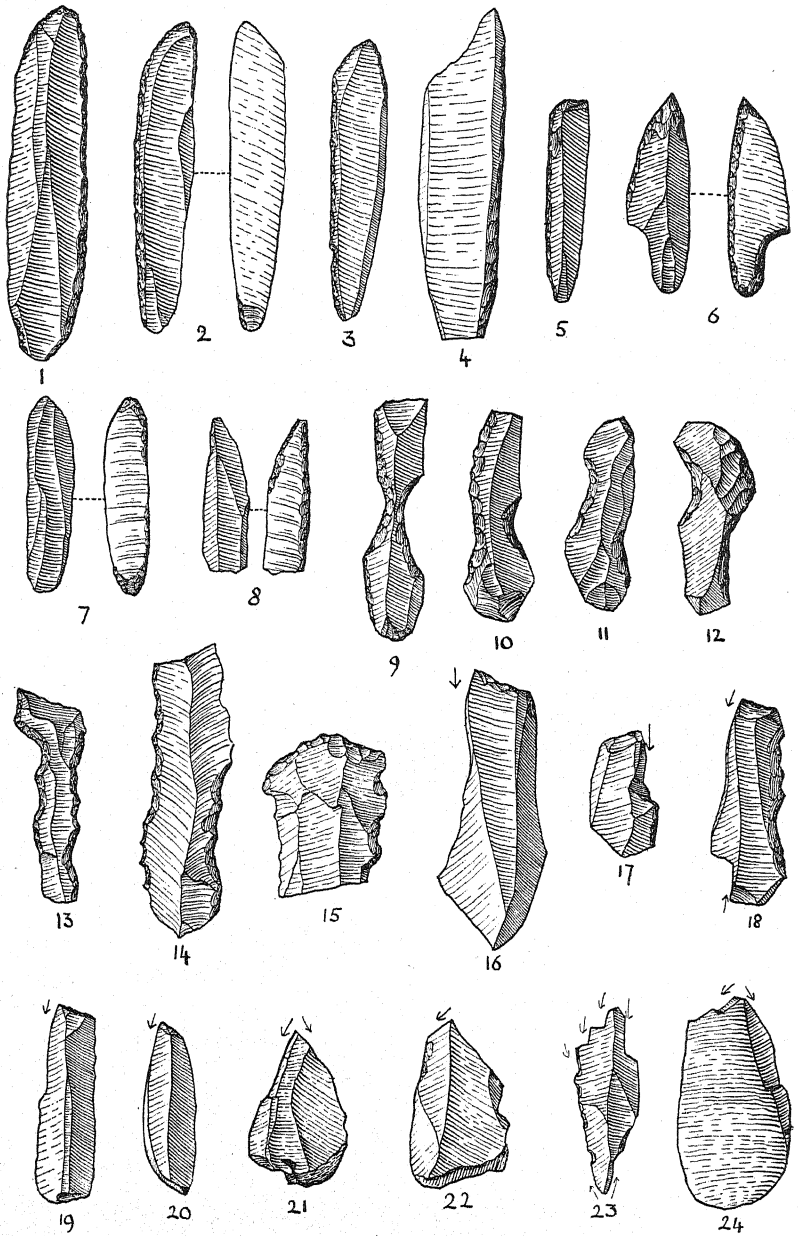

SINANTHROPUS PEKINENSIS FROM CHOU KOU TIEN



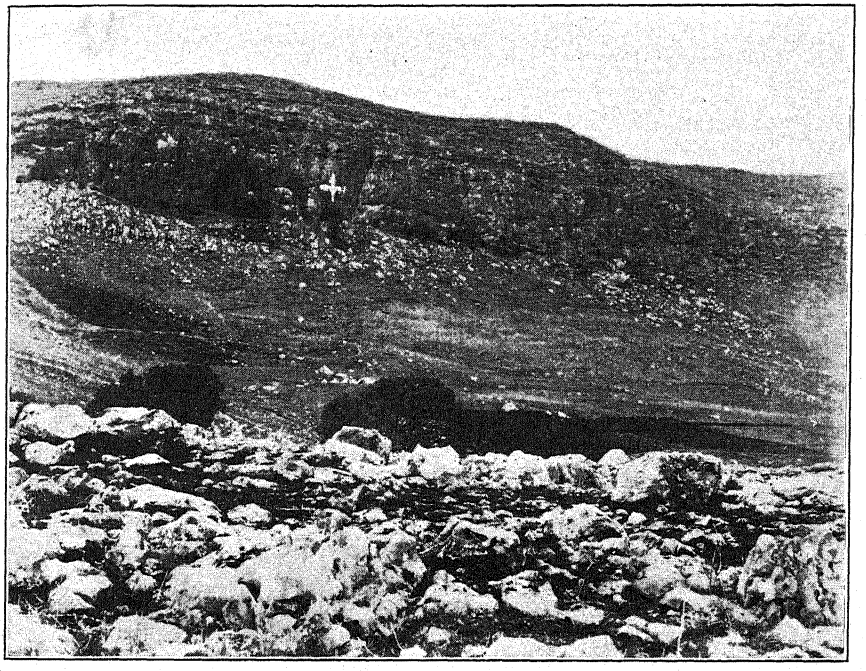
1. ZARZI



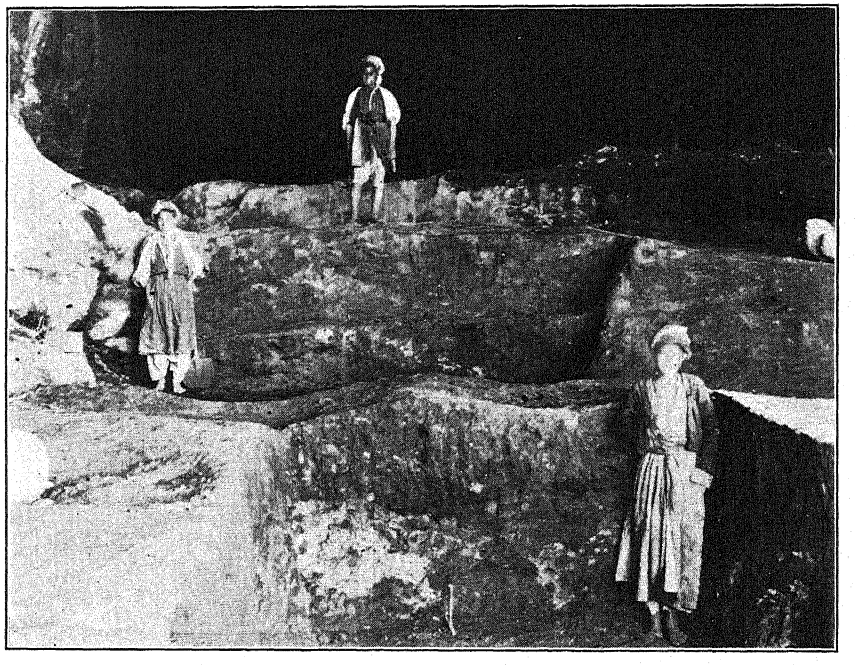
2. ZARZI



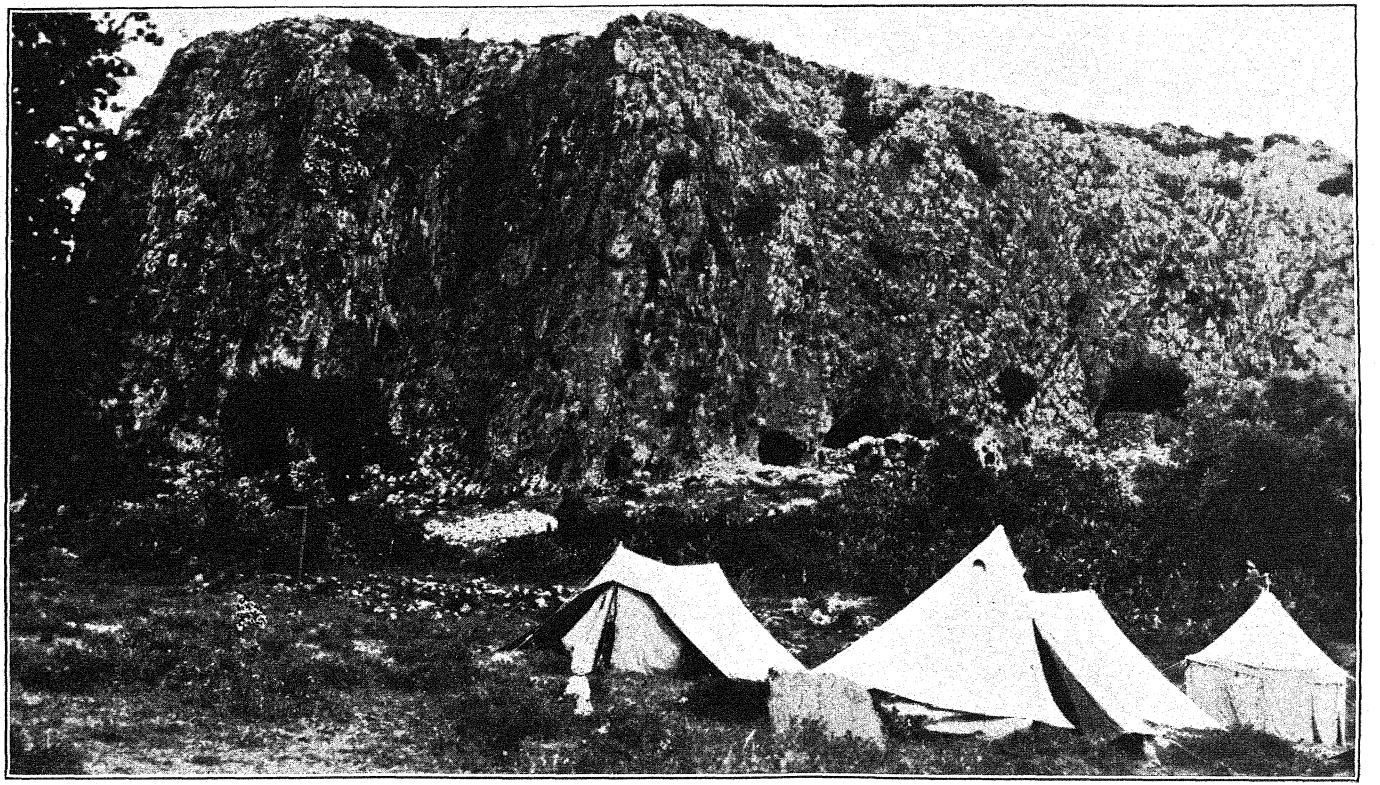

ZARZI. IMPLEMENTS FROM LAYER B



1. HAZAR MERD



2. HAZAR MERD



MUGHARET EL WAD AND CAVE OF THE CAMELS (AT RIGHT)

Père Teilhard de Chardin and Dr. C. C. Young, just issued from the press. Further it should be added that up to the present time, though thousands of cubic meters of material have been examined, no artifacts of any nature have been encountered nor has any trace of the usage of fire been observed.

The greater part of the left lateral surface and the fore part of the base of this unique skull of *Sinanthropus* is still imbedded in a block of very hard travertine.[2] The vault of the skull, from its massive brow ridges to the occiput, and the whole right side of the specimen was, however, supported within a relatively soft matrix which has now been removed. In the present stage of its preparation it thus becomes apparent that the brain case has been almost completely preserved while most of the facial region is lacking. Black says the cranium is that of a young adult female.

The skull of *Sinanthropus* is approximately similar in length to that of *Pithecanthropus* and like the latter form is provided with massive brow ridges, a feature to be correlated with a powerful jaw mechanism. However, *Sinanthropus* characteristically differs from the Java type in the following important features: Relatively well-developed frontal eminences, well-localized parietal eminences and greater height of skull vault, all these characters pointing to a relatively greater brain capacity in *Sinanthropus*.[3] The mastoid processes of *Sinanthropus* are small. The sockets in which the lower jaw articulated are well preserved on both sides, a circumstance which will be of great value in the restoration of the lower jaw fragments recovered in 1928.

In July, 1930, Dr. Davidson Black announced the discovery at Chou Kou Tien (Locus D) of the greater part of the vault and a portion of the base of a second *Sinanthropus* cranium (pl. 4). He believes it to be that of a young though fully adult individual, probably a male. The new specimen has been pieced together from fragments, the broken edges of which fit one another; no other restoration being resorted to in order to produce the results as seen in Plate 4.

This cranium, the second to be found at Chou Kou Tien, yields valuable information concerning certain parts not represented in the first more perfectly preserved specimen. Compared with the latter, according to Black, the new cranium also presents certain slight differences which may be due to a difference in sex. While the new cranium has about the same maximum transverse diameter as the first, its length is greater than the latter by some two centimeters. On the other hand the frontal eminences are not so prominent, nor is the average thickness of the skull vault so great in the second as

[2] The skull has since been completely disengaged. (See pls. 1–3.)
[3] This is not true because of the great thickness of the cranium in Sinanthropus.

in the first specimen. A small part of the left glenoid fossa has been preserved, also the nasal suture and the base of the broad nasal bones.

*Saccopastore.*—The estate of Saccopastore is about 3.5 km. (2.2 miles) from the Porta Pia, Rome. Here in a gravel pit workmen discovered a skull of the Neandertal type in 1929. It was immediately turned over by the lessee of the estate, Signor Casorri, to the Duke of Grazioli, who confided it to the Anthropological Institute of the University of Rome, where it will be preserved. According to Prof. Sergio Sergi, the mandible is lacking but the cranium is in a fairly good state of preservation.

The cranium is characterized by the relatively large facial in contrast with the cerebral portion, as well as the high degree of prognathism and the depression of the vault. The cranial capacity is not over 1,200 cc. and the cranium is that of a female. The remaining teeth, five molars and a premolar, are large. The orbital apertures are very large; the piriform aperture is low and large. The anterior projection of the nasal processes and of the body surface of the maxilla form a kind of snout, not met with in any other known type.

The cranium came from a depth of 6 m. (19.6 feet) in a stratum of sand and gravel, rich in fossil animal remains: *Elephas antiquus*, *Hippopotamus major*, *Rhinoceros mercki*, *Cervus elaphus*, *Bos primigenius*, and others. No artifacts have been found at Saccopastore, but artifacts of the Mousterian type were found in the same strata of near-by sites in the valley of the Tevere and Aniene as early as 1846. These finds with that of the cranium are proof that man lived in Lazio probably as early as the Riss-Würm interglacial epoch.

*Czechoslovakia.*—There are many sand pits and brickyards within and near the city limits of Brno. These are watched continuously for prehistoric relics. In May, 1927, a human skeleton was found in the exploitation in Susilova Street, Zabovresky quarter of the greater city. The skeleton was found in a red sandy loam at the contact between the sand and the coarse gravel at a depth of 2.15 m. (7 feet). It lay in a crouching position in a kind of egg-shaped hollow. The color of the sandy loam about it was deep red. Since the color diminished in intensity radially in all directions from the skeleton, the coloring matter must have been originally a part of the burial. The skeleton, which was in a bad state of preservation, is that of an adult woman and is referred to as Brno III. According to Matiegka, the skull bears the strongest resemblance to the skulls from Combe-Capelle and Mladeč I; also in certain features to Brno II and the female skulls from Předmost.

An additional fossil human skeleton was found at Předmost in 1928. The skeleton, in a fragmentary condition, was found in ashes of the Paleolithic layer, associated with bones of the mammoth.

The proximal end of the left human femur is missing. On the remaining two-thirds, there are scrapings and cuts oblique to the axis of the shaft on its anterior surface all the way up from the lateral condyle. They were done by flint tools and raise the question as to whether cannibalism was practiced at Předmost. In all, 54 bones of the human skeleton were found, at the same level and not far removed from the remarkable communal grave discovered by Maška.

Our knowledge of the fossil fauna associated with fossil man is growing apace. One of these animals was the woolly rhinoceros (*Rhinoceros tichorhinus*) which sometimes served as a model for Cro-Magnon artists. It was a contemporary of the woolly elephant (*Elephas primigenius*). Well preserved examples of both have been found in Siberian ice fields. In 1907 asphaltum deposits at Starunia, Poland, yielded a mammoth (woolly elephant) and woolly rhinoceros, both perfectly preserved. They are now in the museum at Lemberg. In 1929, from the same deposit there was taken another complete woolly rhinoceros, which has been removed to the museum of the Polish Academy of Science in Krakau.

*Cave art.*—The latest researches of Pittard tend to prove that the first example of cave art to be discovered was not the engraving on bone from Chaffaud, but an engraved baton of reindeer horn from the cavern of Le Veyrier, near Geneva (Haute-Savoie). This baton was found by François Mayor in 1833 and reported the same year to the Société de Physique et d'Histoire Naturelle, Geneva. The engraving is not an important work of art. It would be difficult to determine the animal intended to be represented. Mayor also found that which at first glance would seem to be a harpoon. But the point is at the wrong end; so that instead of being a harpoon shaft with barbs, the piece represents a stem in bud. Thus the first engraved object and the first sculptured object dating from the cave-art era were both found at Le Veyrier—on French soil, to be sure, but by a Genevese.

A number of outstanding discoveries in the field of Paleolithic art have been made during the past few years, some of which have not yet been published. I shall mention briefly six of these—one each from Siberia, Italy, England, and Germany and two from France.

*Irkutsk.*—A human female figurine has been found on the Bjelala River near Irkutsk, Siberia. The site is not far from the Chinese frontier. In the same deposits were found fossil bones of the mammoth and woolly rhinoceros. The figurine is of the Brassempouy-Willendorf type. The distance from Brassempouy near the Bay of Biscay to Irkutsk is about 11,200 km. (7,000 miles).

*Savignano.*—A human female figurine was encountered when digging a cellar in 1926 at Savignano-sul-Panaro (Emilia), Italy. It is of the Brassempouy-Grimaldi type and made of steatite. The head

is not differentiated, the feet and arms are not represented, the legs are fused, while the breasts, hips, and ceinture are overemphasized. The figurine is 22.5 cm. in length.

*Petersfels.*—Petersfels is the ninth prehistoric station in Germany, where Paleolithic art has been found. It is named for Herr Peters, the discoverer. The site is near Engen (Hegau), southern Baden, only a short distance north of Kesslerloch in Switzerland, which many years ago yielded the well-known figure of the browsing reindeer. The find includes stone artifacts, bone needles, perforated shells, and teeth, javelin points, batons of reindeer horn, decorated ivory disk, pendants representing the human female form carved from lignite; also engravings on bone and reindeer horn, including figures of the reindeer on a baton. The female figurines are perforated for suspension and are of the Brassempouy-Willendorf type; the head is no longer recognizable, the legs barely indicated and the hips exaggerated. Petersfels belongs to a single phase of the Lower Magdalenian Epoch.

Peyrony reports the finding in the cave of La Roche, near Lalinde (Dordogne), of stones with engraved figures similar in stylistic pattern to the lignite statuettes from Petersfels. The engraved figures from La Roche and the figurines from Petersfels belong to the Lower Magdalenian Epoch; so that they would be contemporaneous with the so-called *venus impudique*, a figurine found years ago in the rock shelter of Laugerie-Basse. The specimen from Laugerie-Basse, while more easily recognizable as representing the human female form, retains nevertheless characters which link it with the examples from Petersfels and La Roche.

The cave of La Roche has yielded something entirely new in paleolithic annals: An oblong object made of reindeer horn, and pointed at both ends, one of which is perforated. One face of this object bears a pattern composed of parallel series of incised lines, some groups being longitudinal and some transverse. This piece had been entirely covered by a coating of red ochre prior to the execution of the incised decoration; it bears a close resemblance to the "churinga" of the Arunta Tribe in Australia and must in its time have served a purpose similar to that served by the esoteric and sacred churinga.

*Trois-Frères.*—In addition to the long series of mural figures discovered at Trois-Frères, recent excavations have yielded remarkable examples of portable art. These finds were made in floor deposits not far from the Enlène entrance, by Mons. Louis Begouen. They include a plaque of ivory on which are engraved figures of two cats seen from the back, also a cricket in profile. Another example is a baton of reindeer horn with engraved figure of a bison. Perhaps

the rarest of all is the head of a wild goat carved from reindeer horn with inlay eyes of another material (burnt bone).

In the summer of 1929 Mons. Begouen found still another example of Paleolithic inlay. It is on the base of a dart thrower, of which the crochet is formed by a bird's beak. On one face of the shaft of the dart thrower there is engraved a goose, the neck bent; on the opposite face the same bird is sculptured in high relief, the head turned backward. The eye is represented by a deep pit in which there was originally an inlay.

*Le Roc.*—The station of Le Roc is situated on a small affluent of the Echelle, in the commune of Sers, some 15 km. southeast of Angoulême (Charente). It consists of two caves—Grotte du Roc and Grotte de la Vièrge—between which is a workshop where the sculptured frieze was found. In addition to the sculptured frieze, engraved figures on limestone were found as follows: Bison and cave bear (on the same piece) from below the Grotte de la Vièrge and a horse from the same trench; a third example is the figure of a bison.

The frieze, which is now installed in the Salle Henri Martin at Saint-Germain-en-Laye, is sculptured on a series of five stones. When found these stones were turned with their ornamented faces against the archeological deposit. As reconstructed, the series from left to right is as follows: First stone, at left, masked man (?), center two horses, right musk ox charging a hunter; second stone, horse facing left; third stone, horse facing right; fourth stone (beneath the third), horse facing right; fifth stone, horse and pseudo-bovidae both facing right.

*El Pendo.*—The first example of cave art ever discovered was an object of the type later known as bâton de commandement. The baton is a piece of reindeer horn or stag horn with one or more perforations and usually decorated. Paleolithic batons have been found sparingly in Austria, Belgium, Czechoslovakia, England, Germany, Italy, Poland, Siberia, and Switzerland. Several dozen have been reported from France, and nine from Spain. The latest one from Spain was unearthed in the cave of El Pendo (Santander) by the Don Jesus Carballo and is preserved in the Museo Prehistorico, Santander. From the viewpoint of art and symbolism, this specimen ranks among the most important. It is of stag horn with a perforation near one end. The entire superficies is practically covered by a series of admirably incised animal heads: Four of *Cervus elaphus* (one stag and three hinds) and one of the horse. These are accompanied by groups of incised lines, some in parallel and some X shaped. This baton furnishes added evidence that the cave artist showed a preference for the female of the species. The three heads of the hind exhibit the same technique as does the hind's head on the baton from

Valle (Santander). The baton from El Pendo was found in the Upper Magdalenian level.

*Creswell Crags.*—From England, poor in Paleolithic art, Leslie Armstrong reports the finding in a proto-Solutrean horizon of one of the caves at Creswell Crags (Derbyshire) the figure of a man wearing an animal mask, engraved on reindeer bone.

*Jordansmühl.*—I can not close this report of progress without mention of at least a few recent discoveries of post-Paleolithic date. There have been many, out of which Jordansmühl (Silesia) should be first considered. The name is well known in prehistory through discoveries made at the Neolithic and Chalcolithic camp site on Bischkowitz hill. In the vicinity of Jordansmühl (west side) are a number of sites dating from the Bronze and Iron Ages, as well as from the Neolithic.

The Jordansmühl ceramic type is distinct from all others. The paste is free from coarse material, the walls of the vessels are thick. The color is dark brown to iron gray. Other types than the Jordansmühl are found in the vicinity.

In 1925 a clay figure of a ram was found in a sand pit on the Klose farm west of Jordansmühl. With it were two clay vessels and a broken flint knife. Although somewhat weathered the figure of the ram has been restored. Its total height is 33 cm., body height 23.5 cm., and length 37 cm. The rugosity of the massive horns is well represented by means of transverse string imprints. The neck and body also bear string imprints. This is a splendid example in clay of the Neolithic potter's art.

*Neolithic art in China.*—The East India Museum of Stockholm has recently come into possession of a ceramic piece dating from the Neolithic Period in China, which is of more than passing interest. It is the lid of a vessel in the form of a human head, neck, and bust. The facial region rises slightly from the spherical head. The chin, nose, and cheek protuberances are perforated; the eyes and mouth are simply oval holes. The brows are prominent. Above and back of the brows there is a pair of pitted protuberances. Beginning at the crown and meandering gracefully down the back of the head and neck onto the bust there is a figure suggesting a Chinese pigtail, but instead it is a serpent, the head (with open mouth) of which rises above the pair of protuberances. Nothing like this has been found in western Asia or southeastern Europe.

*Iberian ceramic art.*—An idea of the excellence of the potter's art in the Iberian Peninsula some 400 B. C. may be had from a study of the Heiss collection, recently published in part by Hugo Obermaier and Carl Walter Heiss. The necropolis from which this collection came is in the region of Archena (Prov. Murcia), southeastern Spain. The paste is a fine reddish yellow clay, the orna-

ment in two colors. A description of one of the vases will suffice to give a fair idea of the group as a whole. The horizontal bands dividing the vase into zones are reddish brown, whereas the zonal decorations are in red. The principal panel (at the shoulder) carries on one side a bird with outstretched wings, on the other a carnivore with open mouth revealing teeth and tongue. Beneath the bird on one side and the carnivore on the other there are in each case a lone elevated bird's wing and a fish. The rest of the ground in each panel is appropriately decorated with plantlike motives. Of the other narrower zones, the middle one is filled by means of a series of S-shaped figures, while each of the two zones below carries a series of concentric half circles. The vase has a pair of vertically placed handles on the shoulder separating the two panels of the principal zone. The ceramic art of Archena is in all respects similar to that in the neighboring region of Elche.

*Iraq and Palestine.*—In closing this account of progress, it is fitting that mention be made of the work being carried on by the American School of Prehistoric Research, especially that in cooperation with the British in Iraq and Palestine. The first joint expedition was in that part of the hill country of southern Kurdistan now included in the Kingdom of Iraq. This region is called Sulaimani and the town of Sulaimani, which lies 265 km. northeast of Bagdad and 45 km. west of the Persian border, has sometimes been called the capital of Southern Kurdistan. Nearly eight weeks in the autumn of 1928 were devoted to reconnaissance and digging.

The cave of Zarzi, 50 km. northwest of Sulaimani, was completely excavated. (Pl. 5.) The chief culture-bearing level at Zarzi is Upper Paleolithic, the equivalent of the Upper Aurignacian at such stations in Europe as Willendorf and Krems in lower Austria and the caves of Grimaldi in Italy. (Pl. 6.) At the top of this level there were found true Tardenoisian types of the Mesolithic Period. The layer directly above this was mixed and yielded crude pottery as well as flint implements similar to those found below.

Work was continued at the caves of Hazar Merd, about 8 km. southwest of Sulaimani. One of these—the Dark Cave (Ashkot-i-Tarik)—was partially excavated. (Pl. 7.) Here three levels were encountered in the floor deposits, the sequence from above downwards being: (*a*) Bronze Age to recent, (*b*) Upper Paleolithic (similar to that at Zarzi), (*c*) Mousterian.

Miss Dorothy A. E. Garrod, representing the Percy Sladen Memorial Fund, was in charge of the expedition. Her report[4] has just been published in bulletin No. 6 of the American School of Prehistoric Research (New Haven, Conn., March, 1930).

[4] The Palaeolithic of Southern Kurdistan: Excavations in the caves of Zarzi and Hazar Merd.

For three months during the spring of 1929, the American School of Prehistoric Research and the British School of Archaeology at Jerusalem made soundings in three caves at Jebba near Athlit, Palestine—Mugharet el Wad (Cave of the Valley), Oven Cave and Cave of the Kid—and partially excavated one, the Mugharet el Wad. The locality is 16 km. south of Haifa and less than 5 km. inland from the Mediterranean shore.

Mugharet el Wad proved to be a very rich site, containing also a more complete series of culture levels than any other site thus far discovered in Palestine. (Pl. 8.) Beginning with the Mousterian Epoch, the cave was occupied almost continuously down to the present. The sequence from the top downward is as follows:

7. Mixed layer with remains of Arab, Byzantine, Roman, Greek, late Bronze, and early Bronze periods.
6. Mesolithic.
5. Upper Paleolithic—Capsian in type, showing probable relation to African culture.
4. Middle Aurignacian in type.
3. Middle Aurignacian in type.
2. Early Middle Aurignacian in type.
1. Mousterian in type.

The artifacts of the Mesolithic layer included small flint crescents and sickle blades, the latter polished through usage along the toothed margins; cores of various sizes and shapes, knives, scrapers, awls, etc. There were bone points, many containing one end intact to serve as a handle; some were small enough to be needles but without an eye, other small ones were pointed at both ends and evidently served as fish hooks; bone harpoons, bone polishing tools, and a bone grooved for hafting microliths or perhaps sickle blades. Objects of adornment included small bone pendants, a bone bead, and various teeth cut and pierced for stringing, the canine teeth of a small carnivore being especially numerous.

The most remarkable of all the finds from this level was a small human head carved from a black and grey banded pebble. The hair and back of the head were left unfinished. The face was done with care: long thick eyebrows, large long eyes, well executed broad but not very flat nose, and prominent lips. The neck was partially completed. The whole is about as large as the end of a man's thumb; this is the oldest human representation found in Palestine to date and may correspond in age to the late Magdalenian of Europe.

The Mesolithic layer of Mugharet el Wad has thus yielded objects hitherto undiscovered in Palestine—the stone human head, the bone haft for microliths and the bone harpoons. To these should be added from the same site a pierced bone resembling a baton and

an animal figure carved in the end of a fragment of long bone, both found previously by Mr. Lambert, assistant director of the Department of Antiquities of Palestine.

Another find new to Palestine was the multiple human burial found by the joint expedition in the Mesolithic layer. This consisted of 10 skeletons—4 adults and 6 children including infants. These had been piled on a hearth prepared for the purpose. The burials were all extended and at various angles. The arm bones of two were interlocked. The head of an infant had been placed on the shoulder of one of the adults. A deer antler, some of the bone pendants and the stone head were all from this burial place, the stone head being directly beneath the skeletons. An additional skeleton was found at the same level in a recess and lying upon its right femur was yet another skull. A flexed skeleton was found in the terrace outside, not far from where Lambert had previously found two skulls only.

Below the Mesolithic, there are four occupation levels which can be definitely referred to the Middle and Upper Aurignacian. In this Upper Paleolithic deposit were found two human jaw fragments and other fragments of human bones, also a number of large human teeth. These and the Mesolithic skeletons will be described by Sir Arthur Keith. The Aurignacian is also rich in artifacts. Beneath the Aurignacian deposit, there is a Mousterian layer some two meters thick. The third joint Palestine expedition (1931) will complete the excavation of this deposit; it will also excavate the nearby Oven Cave and Cave of the Kid.

# ANCIENT SEATING FURNITURE IN THE COLLECTIONS OF THE UNITED STATES NATIONAL MUSEUM

By WALTER HOUGH

[With 24 plates]

The first appearance of detached seating furniture is seen in stools. These are according to the art ideas of the peoples constructing them of varying forms shaped from blocks of wood or stone and having usually four legs. The seats are circular, oval, oblong, and curved, or hollowed out, showing the earliest attempts at adapting the area to the conformation of the body; one might term it a primitive effort at practical anthropometrics. In its simplest form the stool is a circular block of wood such as was used by Peruvian tribes and the Hupa of California (pl. 1, fig. 1), and perhaps the rounded stone blocks of some ancient Pueblos in Arizona.

Specimens from Costa Rica (pl. 1, figs. 2, 3), West Indies, and Tahiti have a projecting handle from one end and many American specimens have a pierced lug with cord for hanging up, showing that this piece of furniture was not commonly used but only on occasion. This phase will be discussed later.

Simple stools were often elaborately carved. Wiener [1] figures a Peruvian stool of which the seat rests on two excellently carved jaguars. British Guiana specimens in the United States National Museum and specimens from that region figured by W. E. Roth [2] and by Koch-Grünberg [3] from the Taulipang and other tribes of North Brazil and Venezuela are carved stools in the form of tutelary animals. These, although evidently used as seats in the house, are cult objects. (Pl. 2, figs. 1, 2, and 3.)

The simple stool has a rather wide distribution in Central America, the West Indies, and northern South America. The limits of its distribution have not been worked out, and it is to be regretted that Baron Erland Nordenskijold did not include the stool in his excellent work on comparative ethnographical studies.[4] The stool also extends

[1] Perou et Bolivie, p. 522. Paris, 1880.

[2] Arts, crafts, and customs of the British Guiana Indians. Thirty-eighth Ann. Rep., Bur. Amer. Ethnol.

[3] Vom Roraima Zum Orinoco, pls. 19, 49. Stuttgart, 1923.

[4] An Ethno-geographical analysis of the material culture of two Indian tribes of the Gran Chaco. Goteborg, 1919.

into the southern United States. The Creeks in 1666 were described as having in their council houses "thrones" for the cacique and important persons and "small formes" around the fire for lesser people.[5]

Aerican stools are invariably cut from the solid, joining being practically absent in Indian arts. In consequence no seats with backs or even rudimentary beginnings of joined backs are seen in continental America, the stool being at first, as suggested, only a buttock prop in the posture of squatting.

In discussing the stone and pottery objects in the form of stools or metates resembling stools from Chirqui, Panama, Dr. W. H. Holmes says:

> As bearing upon the possible use of these specimens it should be noticed that similar stool-like objects are made of clay, the softness and fragility of which would render them unsuitable for use as mealing plates or mortars, and it would also appear that they are rather fragile for use as stools. I would suggest that they may have served as supports for articles such as vases or idols employed in religious rites or possibly as altars for offerings.[6]

From other countries of Central America many remarkable examples showing skill in working stone have been found in archeologic sites. In general they follow the form of the Indian stool cut from a cylindrical block of wood sectioned from a tree trunk. It is altogether likely that the precursors of the stone stools were of wood.

The West Indian specimens surviving are of more aberrant form, in some cases reaching to the rank of chairs. (Pl. 4.) There are three types; the common 4-legged metate form in stone, a hammock form in stone and wood (pl. 3, figs. 1 and 2), and a remarkably advanced form of curved-back chair like a steamer chair which seems to be a development of the hammock type. Specimens figured by Dr. J. Walter Fewkes,[7] used by Prof. O. T. Mason in his description of the Guesde collection, show that the chair represents a man lying on his back with his limbs drawn up to form the legs of the piece. The chair is a unique example of aboriginal furniture design, comparing favorably in art with any ancient Old World specimens. West Indian stools illustrate the advance made by these Indians in culture. In some respects they corroborate the theory that tribes in an insular environment are helped by their situation to develop a high culture.

Among the more remarkable antiquities found in America are the great carved stone seats from the province of Manabi, Ecuador.[8]

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[5] Swanton, J. R., Bull. 73, Bur. Amer. Ethnol., p. 64, 1922.

[6] Ancient art of the Province of Chiriqui. Sixth Ann. Rep., Bur. Amer. Ethnol., p. 29, 1888.

[7] Twenty-fifth Ann. Rep., Bur. Amer. Ethnol., Pl. XCIII, 7, p. 206.

[8] The antiquities of Manabi, Ecuador. By Marshall H. Saville. Contributed to South American Archeology, vol. 1, pp. 23–49, pls. 4–27. The George G. Heye Expedition. New York, 1907.

These seats are found in a limited area, where they occur in considerable numbers. They consist of a base, a support carved in animal or human form, and a U-shaped seat without back. Undoubtedly these seats are of ceremonial character and formed part of the cult objects in the flimsily constructed hill temples which have now disappeared.[9]

In ancient Peru, according to Wiener,[10] movable seats were not used, and the various great works cut from the solid rock called seats have not been explained by archeologists. They have no characteristics of seats.

If the Mayas had simple seats of stone or wood, none has survived to be noted by explorers. Maya sculpture, however, preserves some remarkable examples of thrones. One of these is shown with a seated figure from the hieroglyphic stairway at Copan.[11] The figure is seated on the skin of a jaguar upon an oblong stool, the carved part of which evidently represents woodwork. At one end of the stool is seen the head of a captive, a motive appearing often in Maya art in which gods are represented as seated on bound victims.

The stucco altar piece of a small temple at Palenque shows a throne seat of massive design of jaguar heads and paws, the former being the arms and the latter the feet of this piece. Between the jaguar heads, on an elaborately worked cushion like a hassock, sits a Maya god with right leg horizontal on the cushion and with outwardly flexed arms, in a graceful pose. This masterpiece of American aboriginal art is called the Beau Relief.[12] The original has disappeared through ravages of time, but the drawing made by Waldeck fortunately preserves this marvel of design and modeling, the climax of aboriginal art in the Western Hemisphere. Doctor Holmes, on his visit to Yucatan in 1894, saw enough of the remains of this superb work of art to guarantee the accuracy of the artist Waldeck's drawing. The Asiatic characteristics of this work are noteworthy, but there is no ground for its attribution to any other source than American. So far as known the pose of the being represented is not duplicated in Maya art. The cushion is also unique. (Pl. 6.)

Corresponding to those of America, simple stools are found among the tribes of lower culture in Africa and Asia. So far as may be ascertained, the use of stools is quite general in Africa, but the distribution has not yet been worked out. From the Somali of Berbera on the Gulf of Aden comes a round dish-top, 4-legged stool

[9] A 4-leg curved stool reminiscent of the West Indian type recovered from the muck at Key Marco, Fla., was figured by Frank Hamilton Cushing. Proc. Amer. Philos. Soc., vol. 35, No. 153, pl. 34, fig. 7, Nov. 6, 1896.

[10] Op. cit., p. 520.

[11] Gordon, G. B. Mem. Peabody Mus. Amer. Arch. & Ethnol., vol. 1, No. 6, p. 12. Cambridge, Mass., 1902.

[12] Holmes, W. H. Art and Archaeology, vol. 1, No. 1, p. 1. Washington, July, 1904.

cut from solid wood. (Pl. 7, fig. 1.) The Vai and Ewe of Liberia make elaborately carved, curved, and flat seat stools, some with a center column surrounded by four legs like the stools of the Ashanti. (Pl. 13, figs. 2 and 3.) The Vai and Grebo have another kind of stool of box-shape neatly laid up of squared strips of wood in log cabin fashion. (Pl. 13, fig. 1.) In the Niger-Benue region, multiple-leg stools are found.

In the Belgian and French Congo a great variety of stools are made, some of them remarkable examples of the wood-carver's skill. Among the Baluba and Sankerru is found a one or two legged stool with openwork curved elliptic seat. (Pl. 10, fig. 1.) These suggest the chief's backrest collected by Herbert Ward (pl. 10, fig. 2), and utilized by him in posing his notable bronze statue, "The Chief of the Tribe," in the National Museum (pl. 11). One of the stools in this collection is carved from a log, has a band indicating four legs, and is carved on the back with a lattice or rickrack pattern on which is represented a climbing snake. (Pl. 8.)

An elaborately decorated 4-legged stool with nearly straight seat having projections of human heads at the ends, is from the Congo collection by Herbert Ward. (Pl. 7, fig. 3.) In the Ward collection is also a notable specimen of wood carving consisting of two disks connected with four decorated bowed bands. (Pl. 9, fig. 1.) In another specimen a woman sits on a disk and holds up the seat on her head and arms. (Pl. 9, fig. 2.) As an example of what may be considered acculturation, a 4-legged stool with back braced by thongs is shown from the Gribo of the western Sudan. (Pl. 7, fig. 2.)

In the C. C. Roberts collection in the United States National Museum from the Ashanti of the ivory coast of the Niger River Basin, is a fine stool of hardwood in the form of a leopard, the realistic carving, especially the head, reminding one of the Egyptian carvings of cats. (See Maspero, Art in Egypt, N. Y., 1922, Fig. 195.) (Pl. 12, fig. 2.) Another, from the Cameroon, more conventionally carved, gives an impression of the massive stolidity of an elephant at rest. The handling of masses and relating of lines is worthy of study. (Pl. 12, fig. 1.)

Asia for the most part shows no development of seating furniture, a reclining position and cushions being indicated for the customs of the predominating peoples. Among the less civilized peoples of Malaysia, stools occur. In the island of Nias, round and oblong 4-legged stools for common use are seen. (Pl. 14, figs. 1–3.) Figures of ancestral gods in carved wood are sometimes seated on a 4-legged stool and also on a cylindrical support. (Pl. 15, figs. 1–2.) The Tagals of the Philippines make 4-legged joined bamboo seats, but these may or may not show traces of acculturation. (Pl. 16, figs.

1–2.) A well-finished hardwood stool from Tahiti indicates that the Polynesians of this island had advanced to the use of seating furniture. (Pl. 17.)

Otherwise among the Polynesians the only example noted is a 4-legged stool from Hawaii illustrated in the Edge-Partington and Heape Album. The seat is practically absent in the islands of the Pacific.

The simpler forms of seating furniture were widespread in Europe. Not until the seventeenth century did chairs become usual. Until the middle of the sixteenth century a chair in the hall or in the master's chamber was the rule and was "the chair," hence chairman for presiding officer. Others sat on benches or movable forms. Benches and chests formed the basis of the interesting development of household furniture in Europe. This subject has been excellently treated by H. Clifford Smith.[13] The ancient stool was also common in the folk furniture of Europe, but it was always joined. It is said that an inventory of 1624 at Gilling Castle, Yorkshire, mentions only two chairs, but lists 35 stools. Also, in 1669, when Charles II entertained the Grand Duke of Tuscany at dinner, the only chair was provided for the guest of honor.

In the ancient centers of civilization something may be recovered of the manner of seating furniture used. Monuments give in some cases abundant data. The statue of Gudea, about 2500 B. C., shows this king seated on a stool having four feet. The pairs of legs at the ends are pierced, giving them somewhat the form of the capital letter A. Upon these rests the seat. The ends were probably cut from a single slab of wood and the seat joined on by a mortise. (Pl. 18.) On the monument of Hammurabi, 2267–2213 B. C., at Susa is represented that king before the sun god, Sammas. The sun god is seated on a low chair throne which seems to be joined work of slats of wood symmetrically arranged, as seen in the quadrangular panel at the side of the throne presented in the relief. (Pl. 19.) A more elaborate seat and other remarkably designed furniture is seen in a votive tablet from Sippur, Mesapotamia. (Pl. 20.) The explorations of Doctor Woolley at Ur bring to light a similar scene of about 2700 B. C., showing a figure seated in a joined chair with rungs, cushion, and back. This chair is of superior design and workmanship and is to all intents and purposes a modern piece of furniture.[14] (Pl. 21.)

Furniture, it appears, reached its greatest development of ancient times in Egypt. For variety, taste, and cabinetmaker's skill, the

[13] Catalogue of English furniture and woodwork. Vol. 1, Gothic and Early Tudor. Publication of the Victoria and Albert Museum, London, 1923.

[14] Museum Journal, vol. 20, No. 1, p. 28. Philadelphia, 1929.

furniture of Egypt contrasts favorably with that of any period. Wall paintings show the manufacture of chairs and other furniture, workmen making parts, indicating the division of labor. It is very likely that Egypt must be looked to for the first great development of joinery. Even with our knowledge of the skill of the Egyptians in designing furniture, the luxurious pieces taken by Howard Carter from the tomb of Tut-Ankh-Amen excite our liveliest wonder. The ordinary people, in the midst of sumptuous furniture enjoyed by the favored, were content with the very ancient stool.

Greek furniture reflects the art feeling of that highly cultured nation. The chair in which sits Aphrodite as portrayed by the Tanagra artist of Boetia in the figure in the Berlin Museum is a work of splendor, massiveness, and genius. (Pl. 22.) A cast of a great seat of carved marble which was the chair of Dionysos Eleuthereus from the theater of Dionysos at Athens, fifth century B. C., is exhibited in the British Museum. (Pl. 23.)

Something is known concerning the cult usages connected with the stool or simple seats mentioned as occurring among uncivilized tribes; more with regard to joined chairs appearing in the higher civilizations and the thrones or seats of honor of gods and monarchs.

W. C. Farabee states that the men of the Jivaro Indians of Eastern Peru sit on stools and the women must sit on the floor.[15] The stool here is the particular possession of men. In British Guiana the Indians have in their houses stools that are used indiscriminately and others carved in the form of animals as the alligator and "tiger," upon which a candidate for admission into a society was made to sit down during initiation. Stools in animal shape evidently had a fetishistic intent.[16] Divining seats carved in the form of the macaw or tiger and alligator combined are used in the practices of the Arawak doctors of British Guiana.[17]

According to observers of 1556 the Samoyed shamans of Siberia have a stool with a back which they use in their incantations. Reference is also made to a similar seat from the Indians of the northwest coast of America.[18] It is probable this seat went out of use among these Indians many years ago. From the description, "An arm chair of cedar boards without legs," apparently a modified chest is meant.

Here and there are found traces of the employment of special seats for the rituals of initiation and other purposes outside of domestic uses. The idea here appears to be localization of the per-

[15] Tribes of Eastern Peru. Papers Peabody Museum, vol. 10, p. 116, Cambridge, Mass., 1922.

[16] W. E. Roth, 38th Ann. Rep., Bur. Amer. Ethnol., p. 274, 1924.

[17] W. E. Roth. Animism and folk lore of the Guiana Indians. 30th Ann. Rep., Bur. Amer. Ethnol., p. 330.

[18] Jackson. The great frozen land. London, 1809, quoting Hakluyt, vol. 1, pp. 317–318.

son or object honored, much as cult images are seated and placed in temples.

The placing of effigies of gods on bases or thrones may have a bearing on seating furniture. This interesting phase was suggested to the writer many years ago by the late Dr. Stewart Culin. The more primitive images had no bases except in some cases a necessary device to secure equilibrium. The square plinth appears to be the first move toward the placing of images. Art and religion, inseparably associated in a constructive way for a long period, were the determinative causes of the development of placement.

Seats required in occupations form an interesting series of objects. The only American occupational seat is a 3-legged stool upon which the Eskimo hunter sits while fishing through the ice. The seat is a light, well-made piece of joined work. Occupational seats perhaps present the first diversification of seating furniture, of which our great variety is the culmination.

The general distribution of chairs in civilized countries shows one of the notable developments of modern progress. From the simple benches and stools of the seventeenth century there has come a great variety of seating furniture satisfying every need for art, luxury, taste, convenience, and practical use.

It is suggested that development of seats, aided by art and invention, was fostered by the increasing delicacy and complexity of the costumes of men and women. It is likely that the modification of seats beyond the simple stool was mainly through the factor of fashion except in the special uses mentioned. This is plainly seen in the head rest[19] originating in response to fashion in hair dressing.

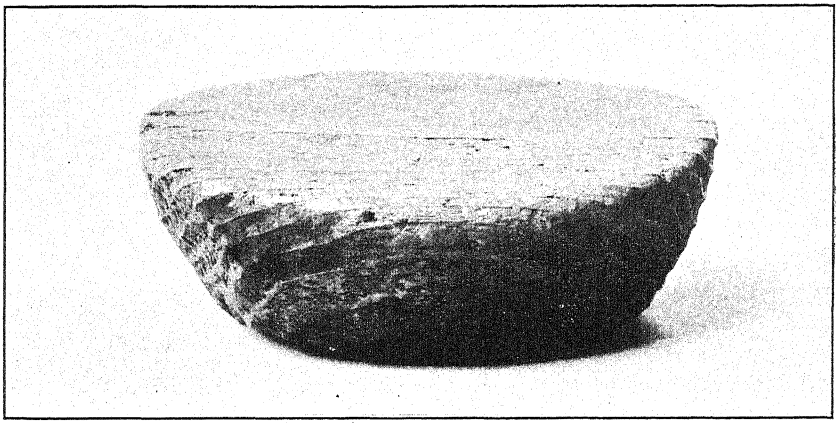
In spite of modern vaunted progress, it seems that the efforts of the present age go little beyond that displayed in the furniture of ancient Egypt except in materials and mechanical arts. The industry, however, has grown to enormous proportions. The outstanding invention of our age is the ancestorless rocking chair. Folding chairs which seem to be consonant with modern invention have an ancient history, it being known from surviving specimens recovered in Europe that Roman generals carried iron folding chairs into the field. A drawing on a Greek amphora of about 500 B. C., in the United States National Museum represents a figure seated on a folding chair of metal. (Pl. 24.) A Greek black-figured plate of the sixth century B. C., in the Royal Ontario Museum of Archeology, Toronto, Canada, shows Dionysos and Poseidon seated on such chairs with Athene standing between them.[20]

[19] F. Graebner, Kopfbanke. Ethnologica. Band. III, pp. 1–14. Leipzig, 1927.
[20] Bull. Royal Ontario Museum of Arch., January, 1929 (frontispiece).

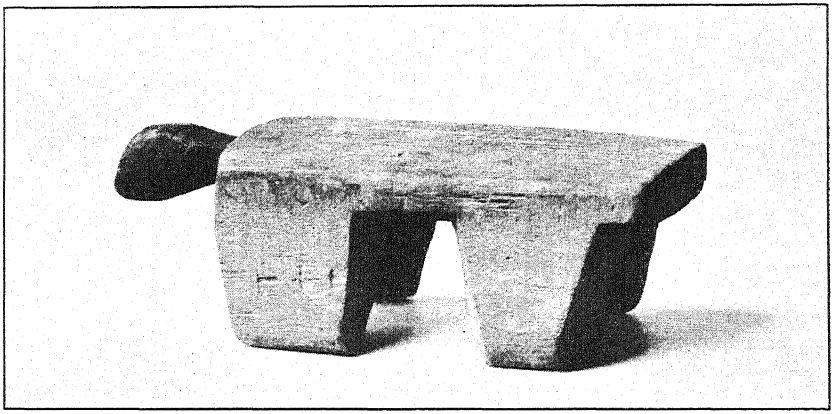
The use of animal forms so prevalent in the art of stools and chairs is apparently normal in all art at a certain stage and grows out of the importance of animals in cult. The stool in many cases is nothing more than a practical appliance for raising the body from the ground, but at times is found to take on a cult phase due to social advances, that is, it becomes an adjunct of social superiority and is designed accordingly to convey some symbolic evidences of power. Chairs set apart the sitter and elevate him in more than one sense. Hence seats are made in the form of totemic animals or those supposed to possess attributes of cunning, strength, or ferocity.

Whatever of suggestiveness aside from cult ideas was involved in the animal-leg furniture of Egypt it is difficult to say. The artist in designing furniture would be likely to know more ancient models which he would use, or he might see that a 4-legged chair or couch suggests a quadruped intended to bear the weight of the sitter and thus be led to model the legs after some animal. Unquestionably these changes in style are frequent and are characteristic of the designer's art, but it is logical to trace them back to the animal cults of the mythologic period so convincingly elaborated by Andrew Lang in his Myth, Ritual, and Religion.[21] In many, perhaps a majority of cases, the practical side of seating furniture is seen to develop parallel with cult ideas introduced into seats. These are seen in the illustrations of many seats carved out in curious forms and lavishly decorated but evidently expressing no cult idea.

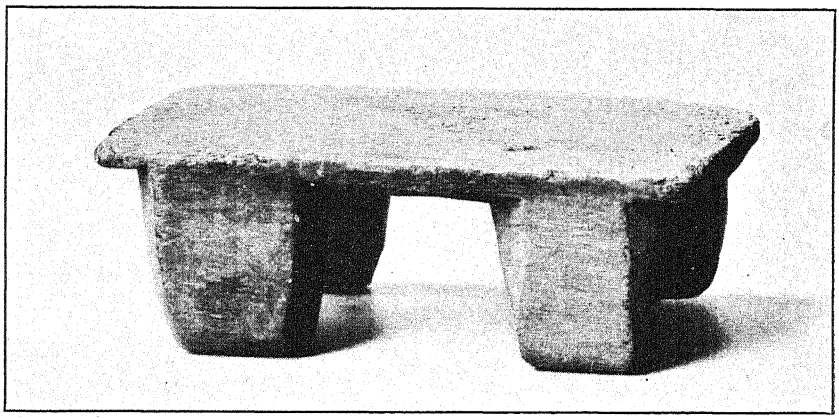
[21] Vol. 11, p. 339. London, 1901.



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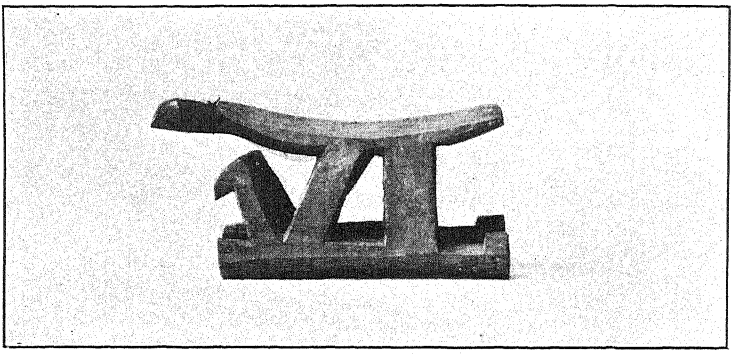
2



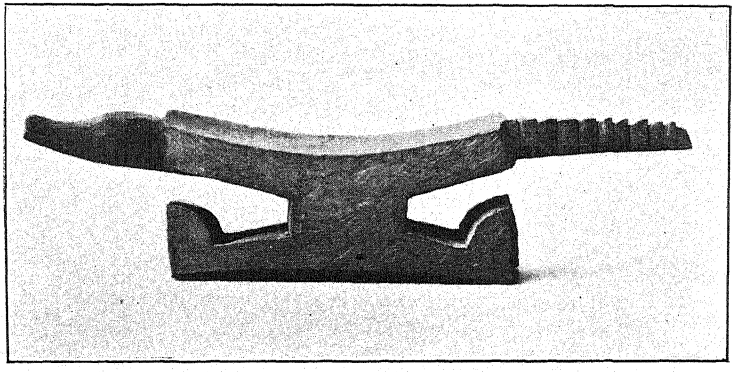
3

SIMPLE STOOLS FROM THE (1) HUPA INDIANS, CALIFORNIA, AND (2, 3) THE TALAMANCA INDIANS, COSTA RICA

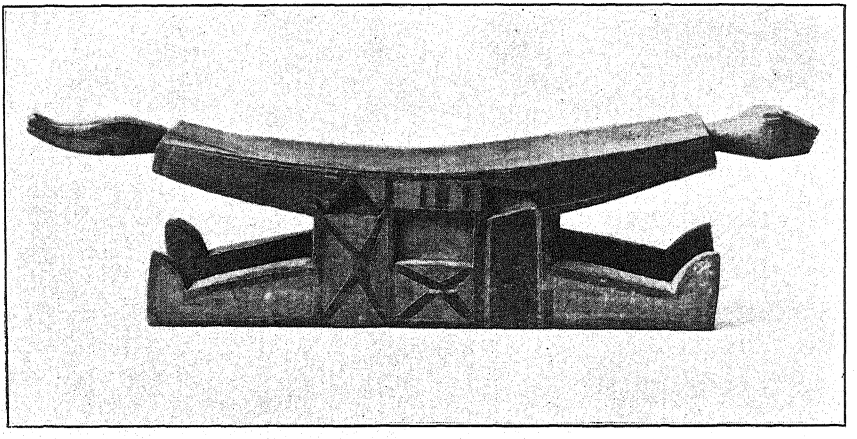
Cat. Nos. 126523, 15461, 15448.



1



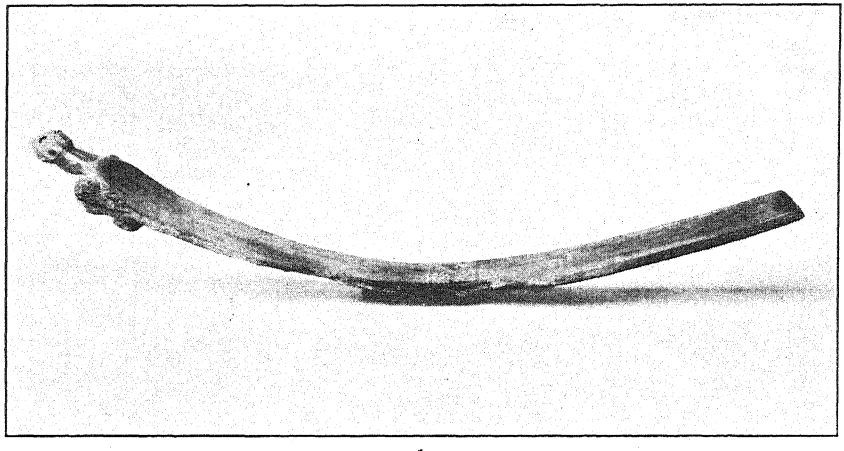
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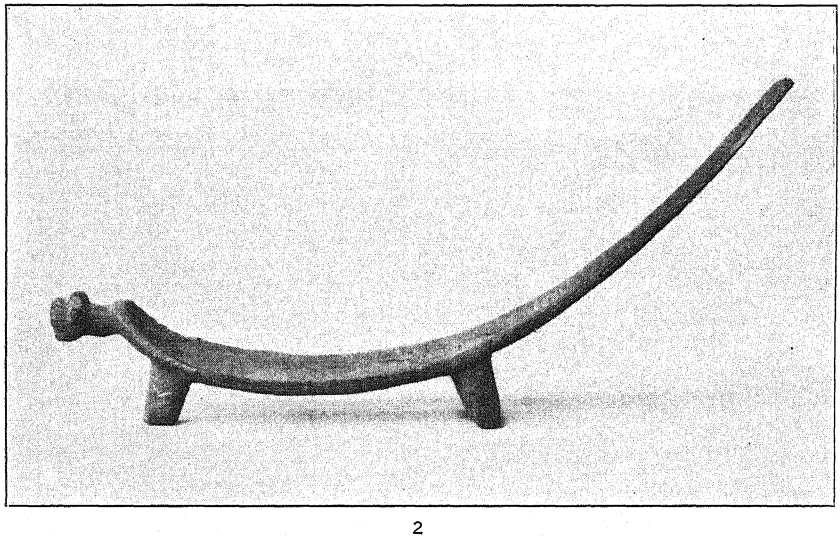
3

ANIMAL FORM SEATS, BRITISH GUIANA

1, Praying mantis; 2, alligator; 3, turtle-alligator. Cat. Nos. 291727, 291760, 291724.



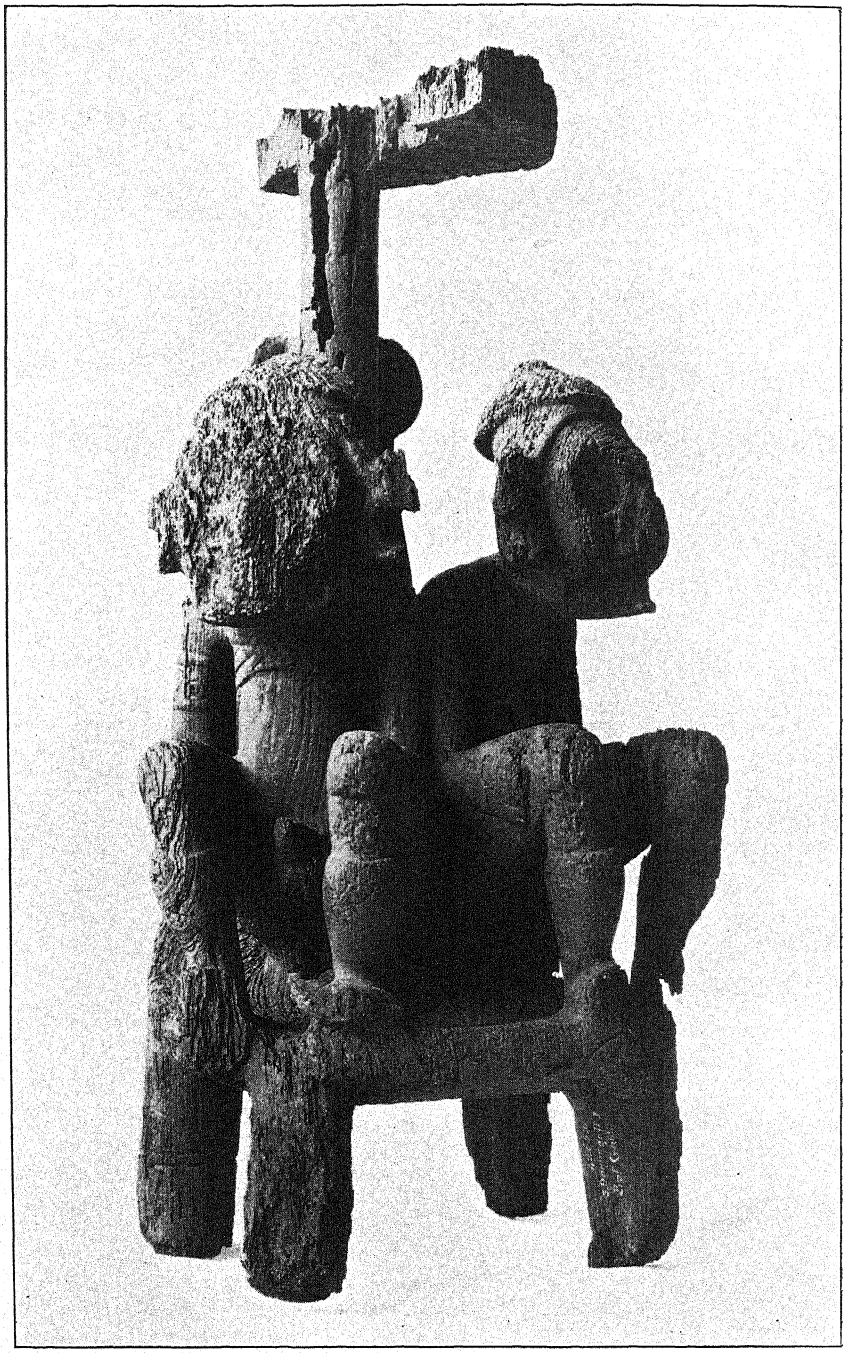
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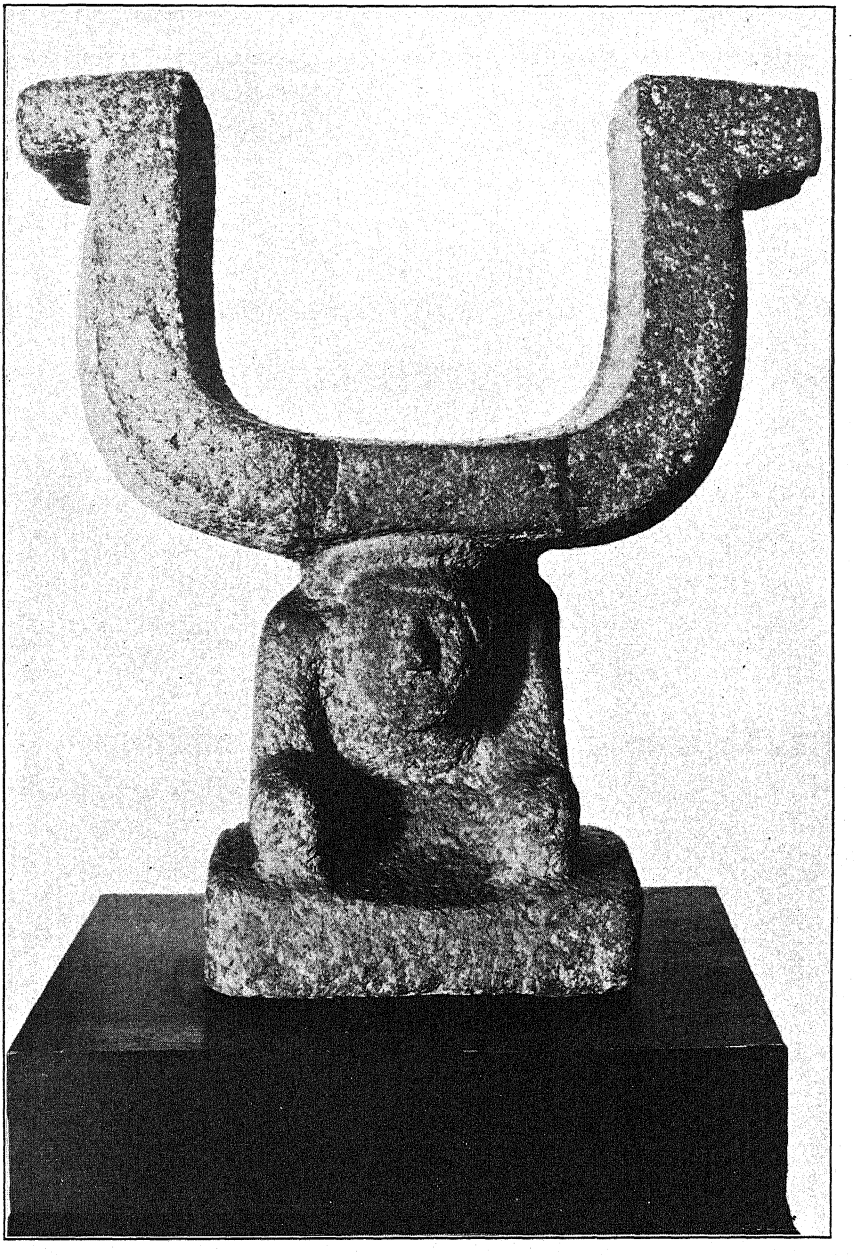
WEST INDIAN CARVED WOOD SEATS, "HAMMOCK" TYPE, TURKS ISLAND

Cat. Nos. 30052, 30053.

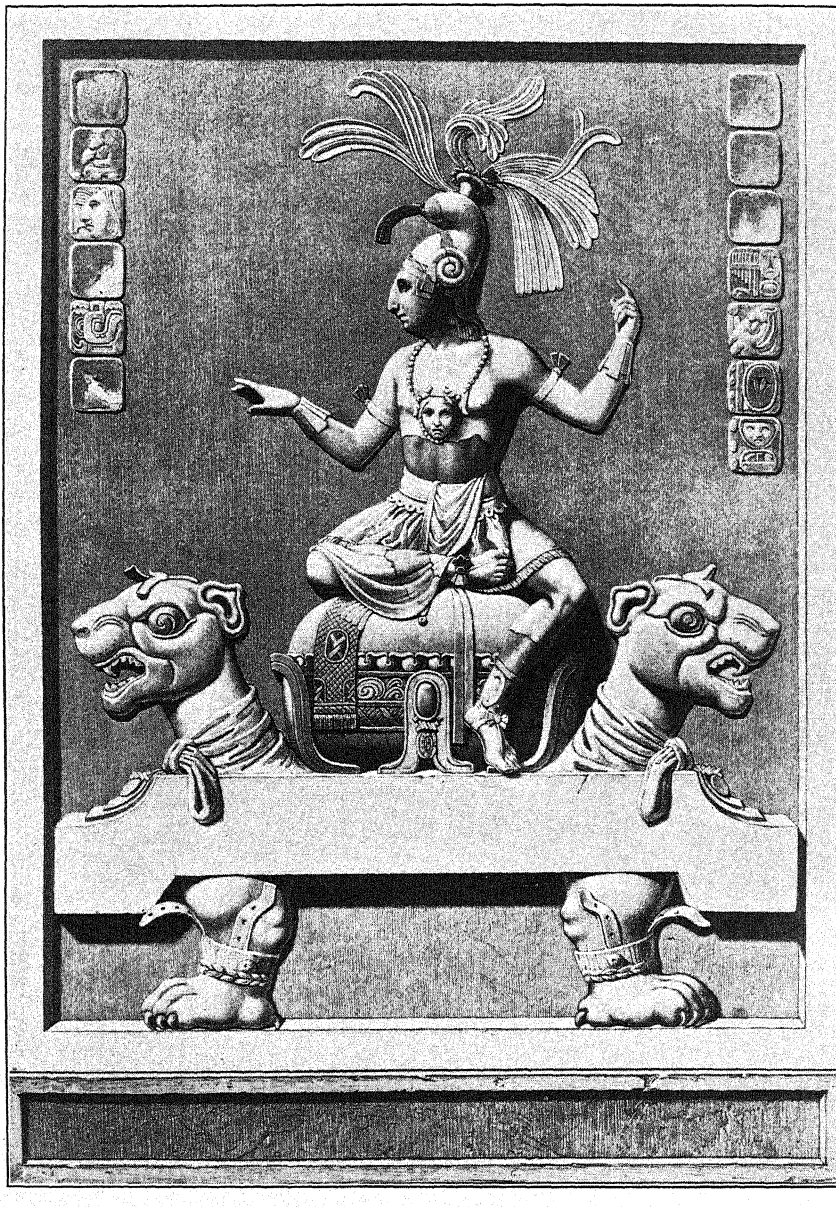


CARVED WOOD GROUP, TWO FIGURES SEATED ON A 4-LEG STOOL. SANTO DOMINGO

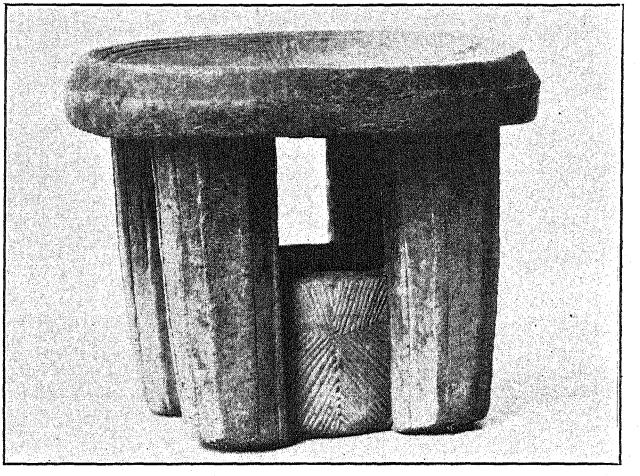
Cat. No. 42662.



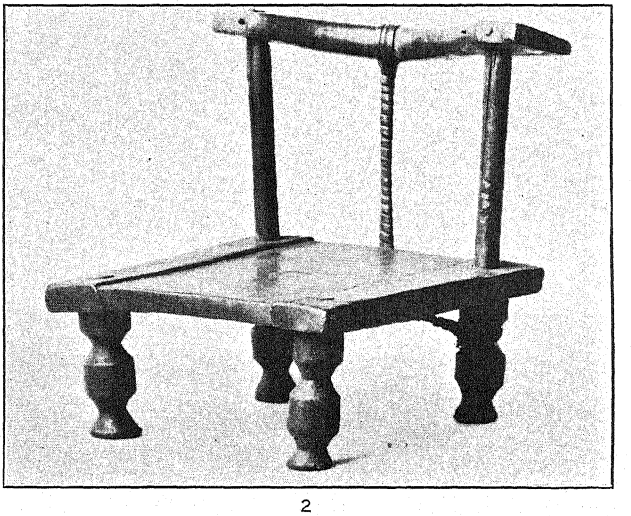
MASSIVE STONE SEAT. MANABI, ECUADOR
Cat. No. 204905.



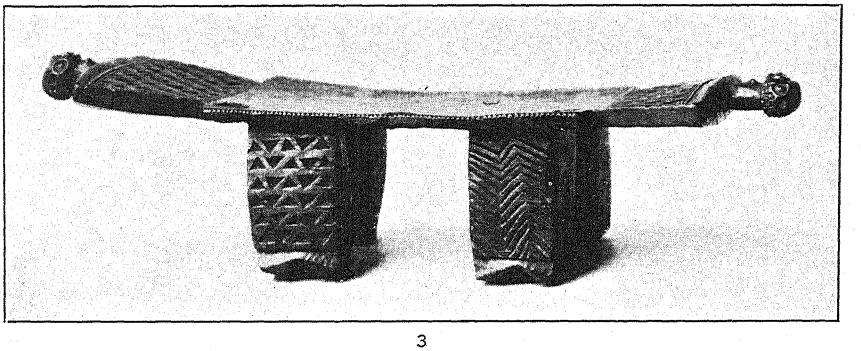
THE BEAU RELIEF. PALENQUE, YUCATAN, MEXICO, FROM DRAWING BY WALDECK



1



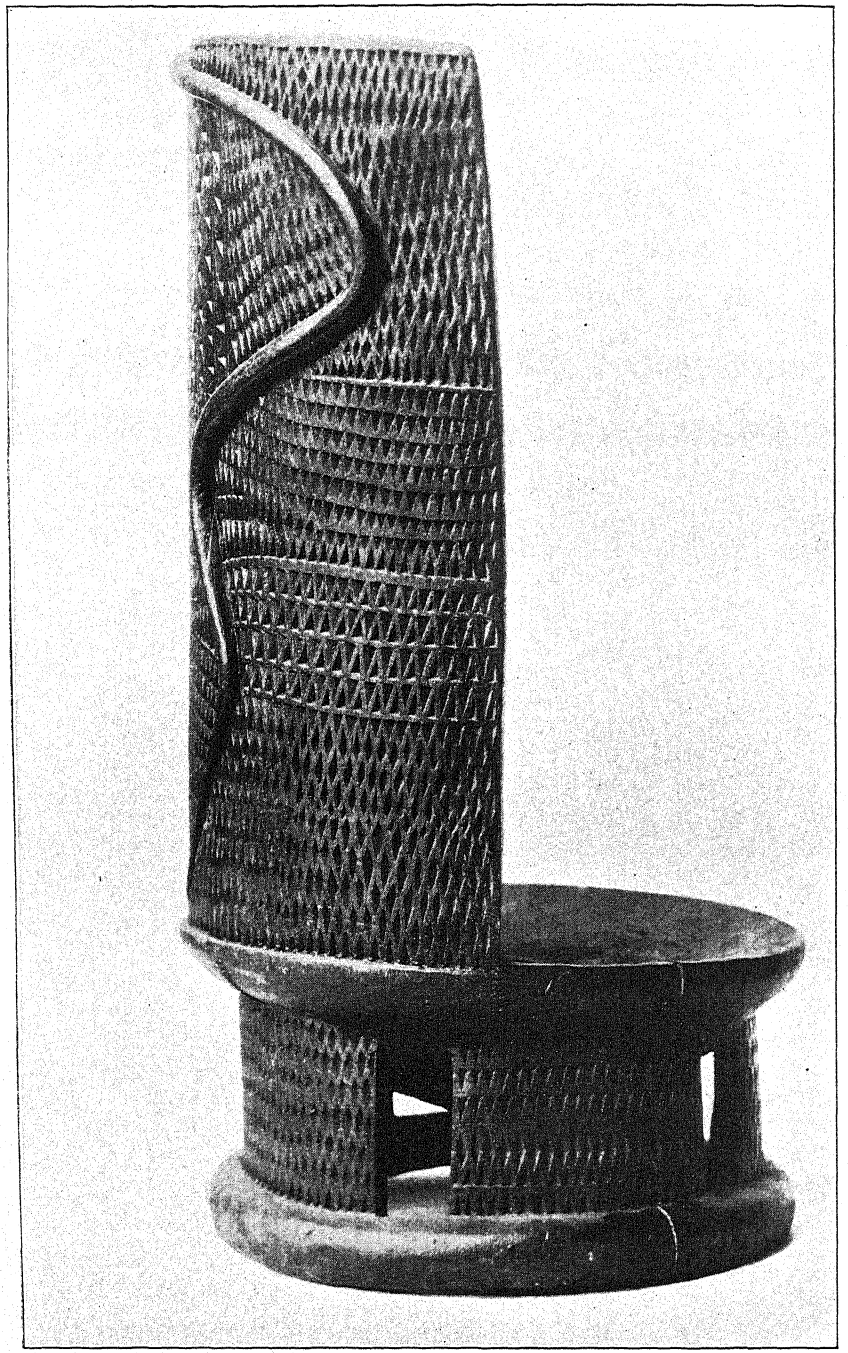
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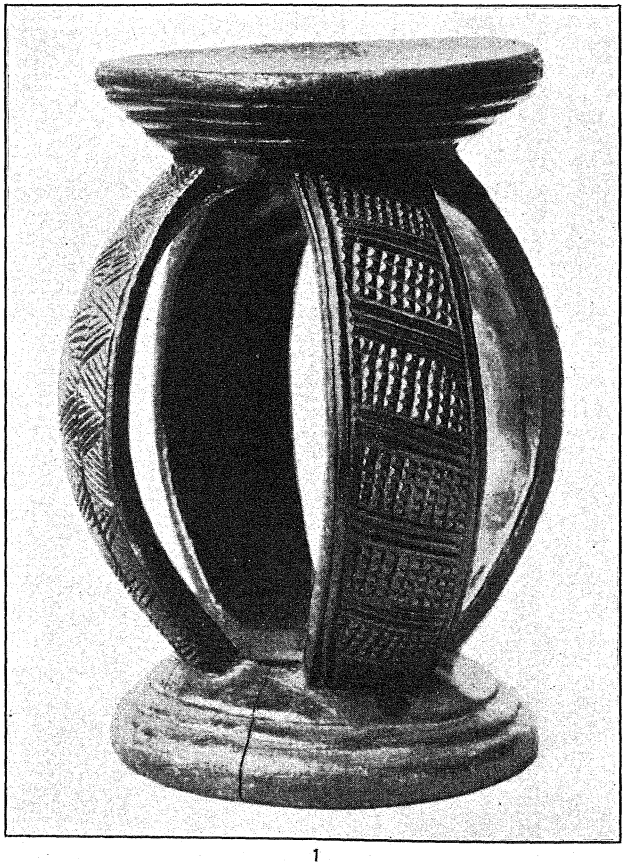
3

AFRICAN CARVED STOOLS

1, Somali, East Africa; 2, Grebo, Western Sudan; 3, Upper Congo. Cat. Nos. 175316, 261642, 323456. Herbert Ward and other collections.



STOOL WITH BACK. UPPER CONGO
Cat. No. 323448. Herbert Ward collection.



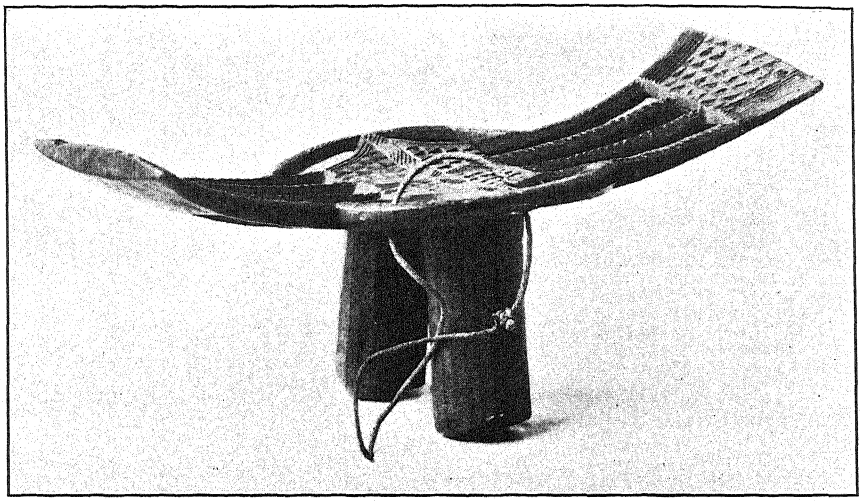
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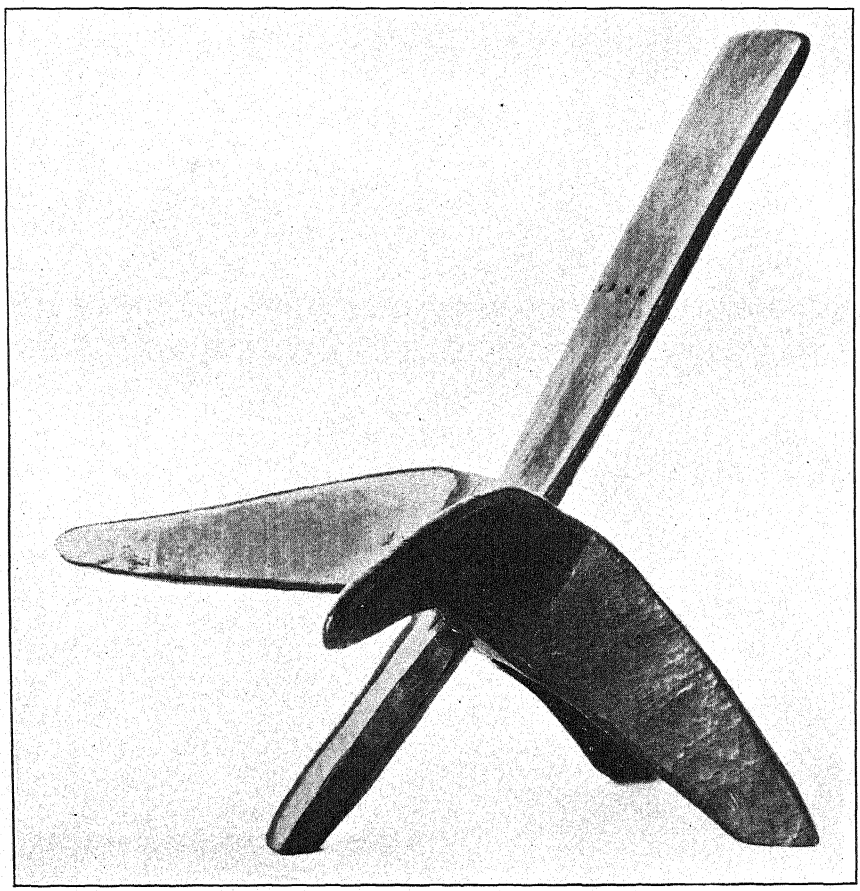
2

CARVED STOOLS, UPPER CONGO

Cat. Nos. 323449, 323315. Herbert Ward collection.



1



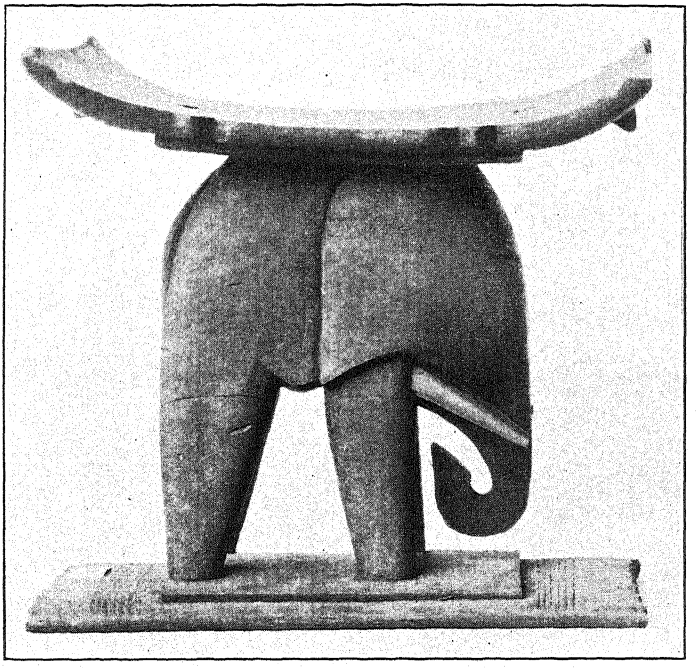
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TWO-LEG STOOL AND CHIEF'S BACK REST, UPPER CONGO

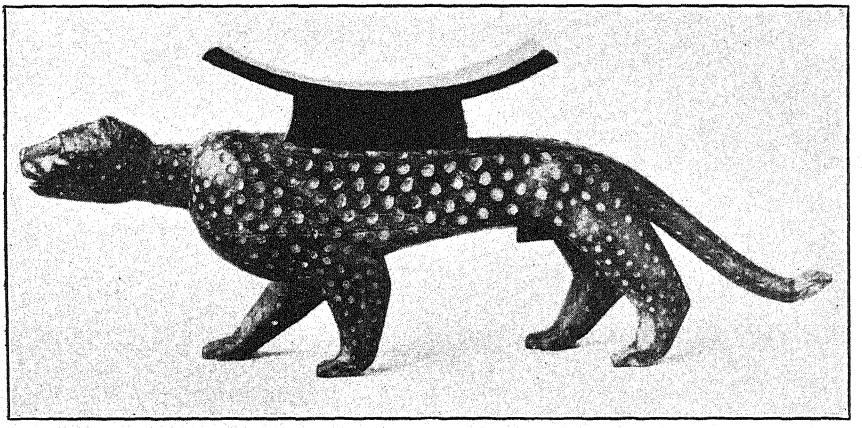
Cat. Nos. 174760, 323659. Herbert Ward collection and Dorsey Mohum collection.



CHIEF OF THE TRIBE. SCULPTURE IN BRONZE BY HERBERT WARD, SHOWING USE OF BACK REST. UPPER CONGO, WEST AFRICA



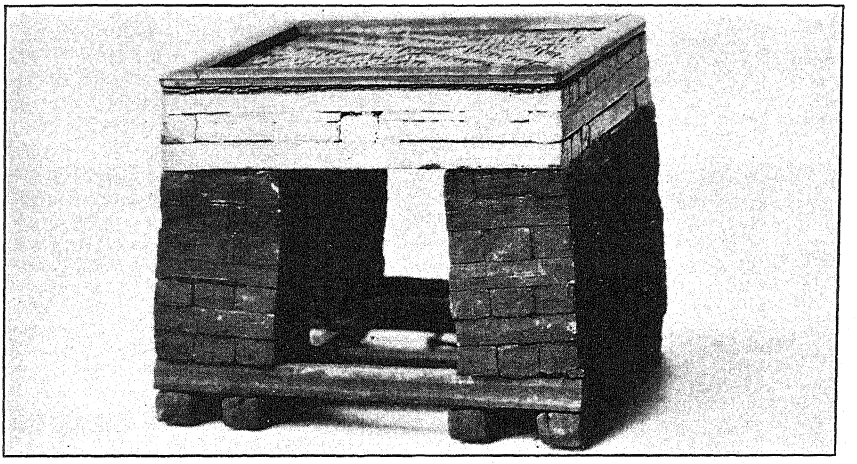
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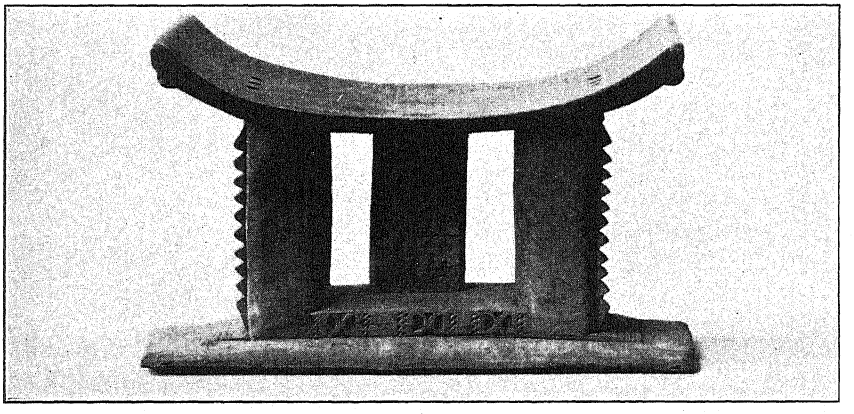
2

CHIEF STOOLS IN FORM OF (1) ELEPHANT AND (2) LEOPARD. UPPER IVORY COAST, WEST AFRICA

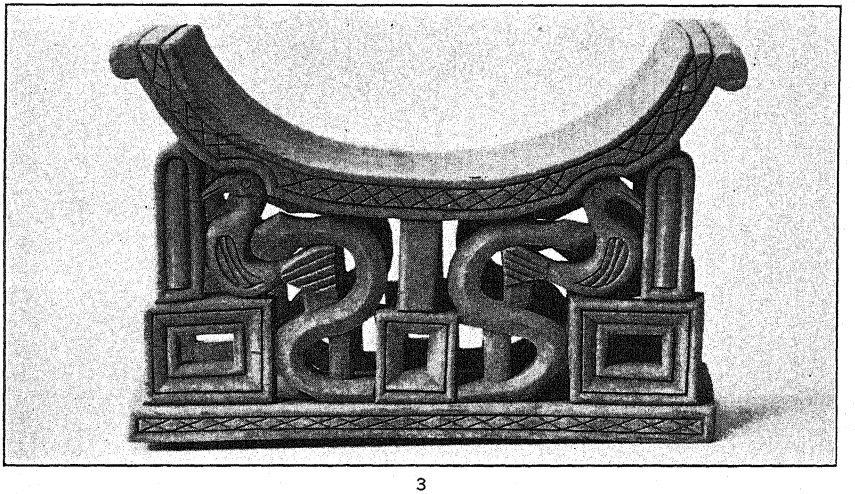
Cat. Nos. 349130, 349131. C. C. Roberts collection.



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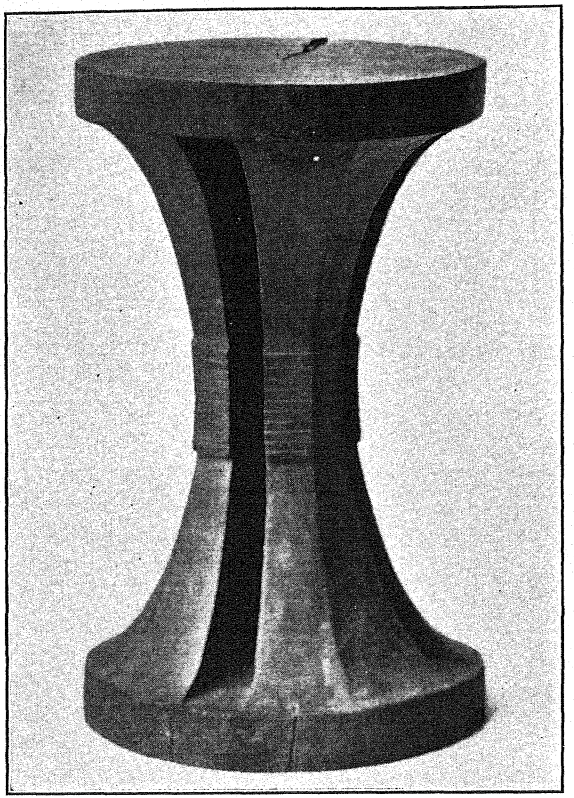
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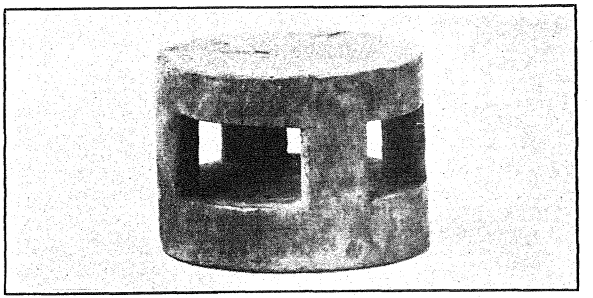
3

JOINED STOOL AND CARVED STOOLS. LIBERIA AND KAMERUN, WEST AFRICA

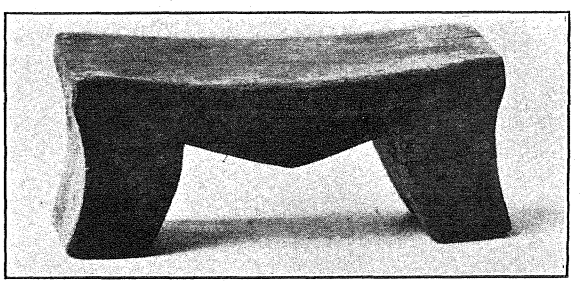
1, Vai, Liberia; 2, Gold Coast; 3, Kamerun.



1



2



3

HOURGLASS SHAPE, CYLINDRICAL, AND OBLONG STOOLS. MALAYS, NIAS ISLAND, EAST INDIES

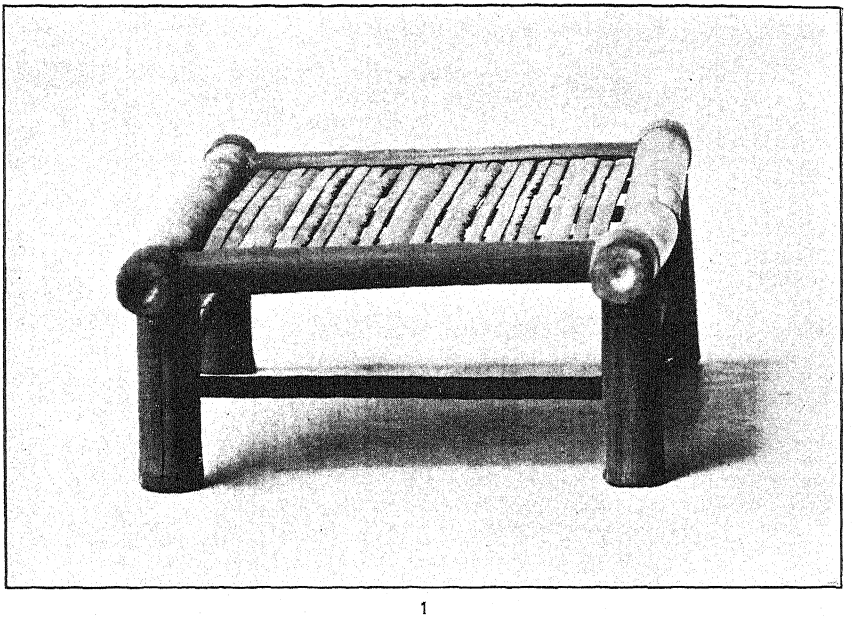
1, Luagunde; 2, 3, Telok Dalam. Cat. Nos. 237462, 237176, 237137. W. L. Abbott collection.



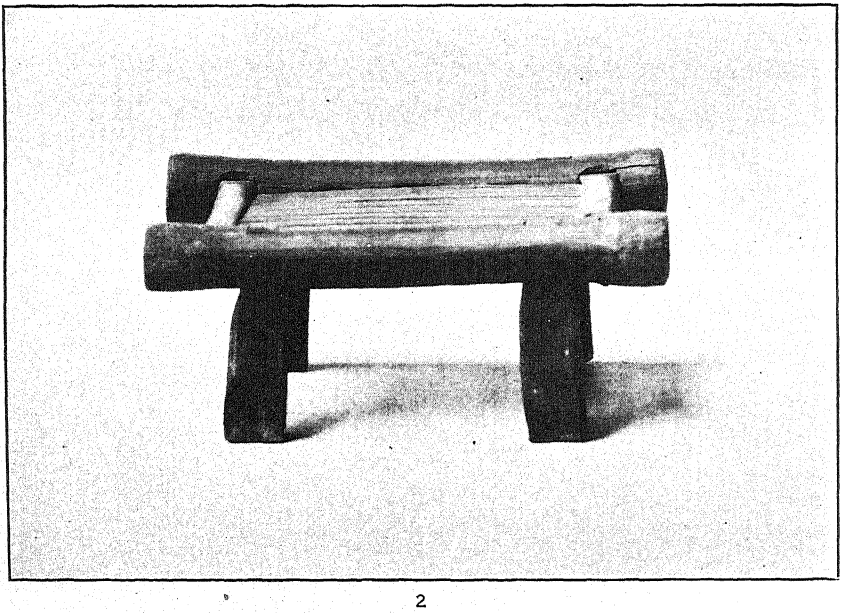
1 2

ANCESTRAL GODS SEATED ON STOOLS. MALAY, NIAS ISLAND, EAST INDIES

1, Terraced throne seat; 2, simple stool. Cat. Nos. 256601, 237384. W. L. Abbott collection.



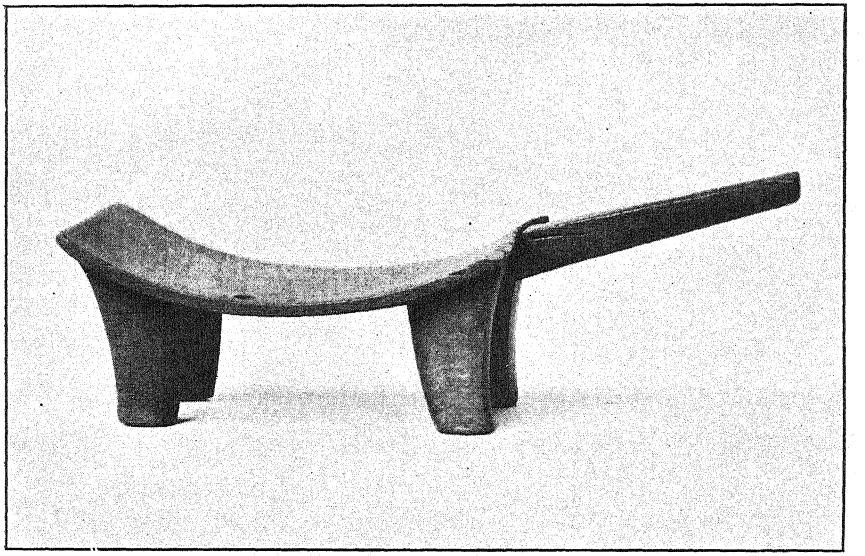
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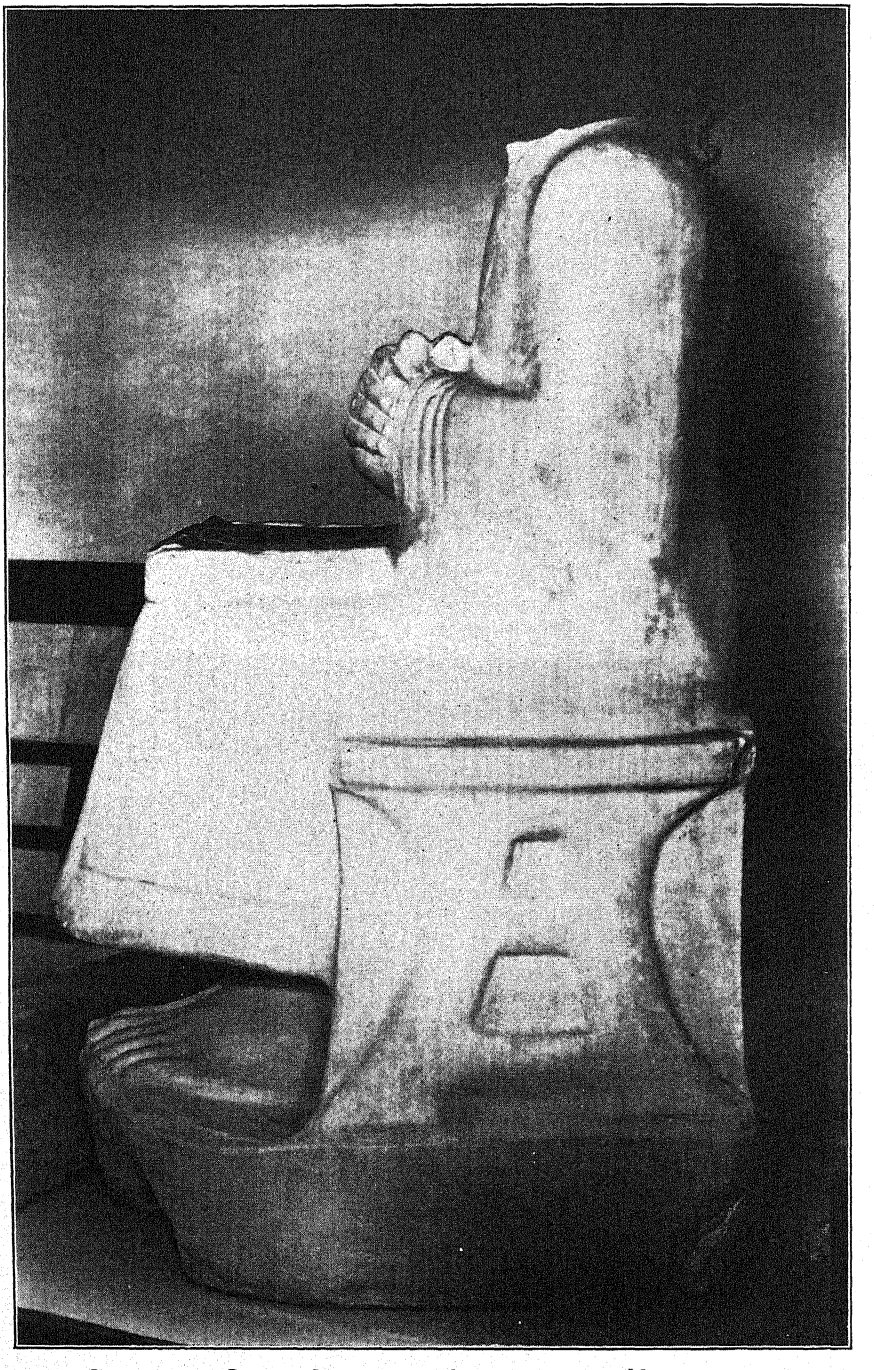
2

BAMBOO STOOLS. TAGALS, LUZON, P. I.

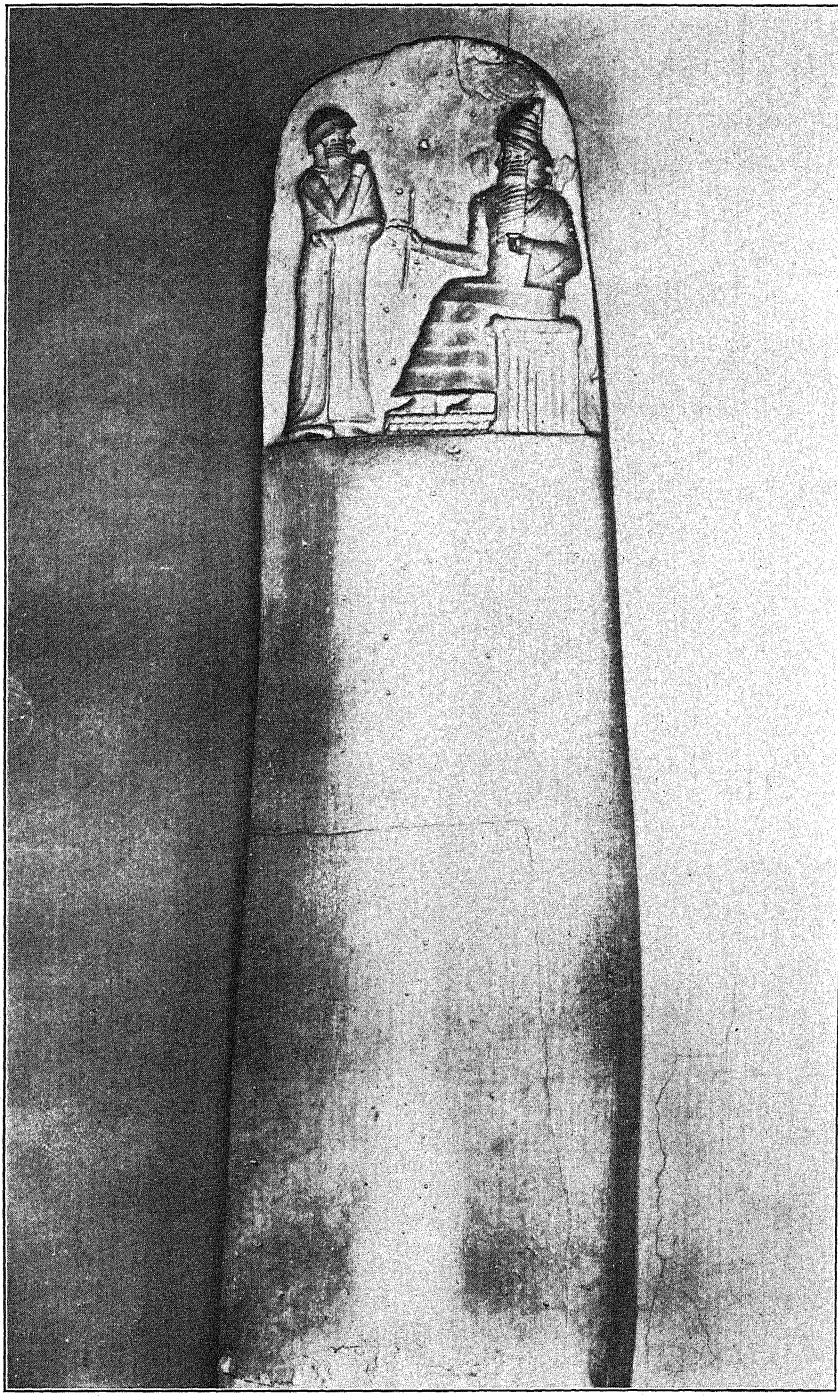
1, With carved slats; 2, simpler stool with wooden legs. Cat. Nos. 216683, 216684.



HARDWOOD SEAT WITH HANDLE. TAHITI
Cat. No. 178603.

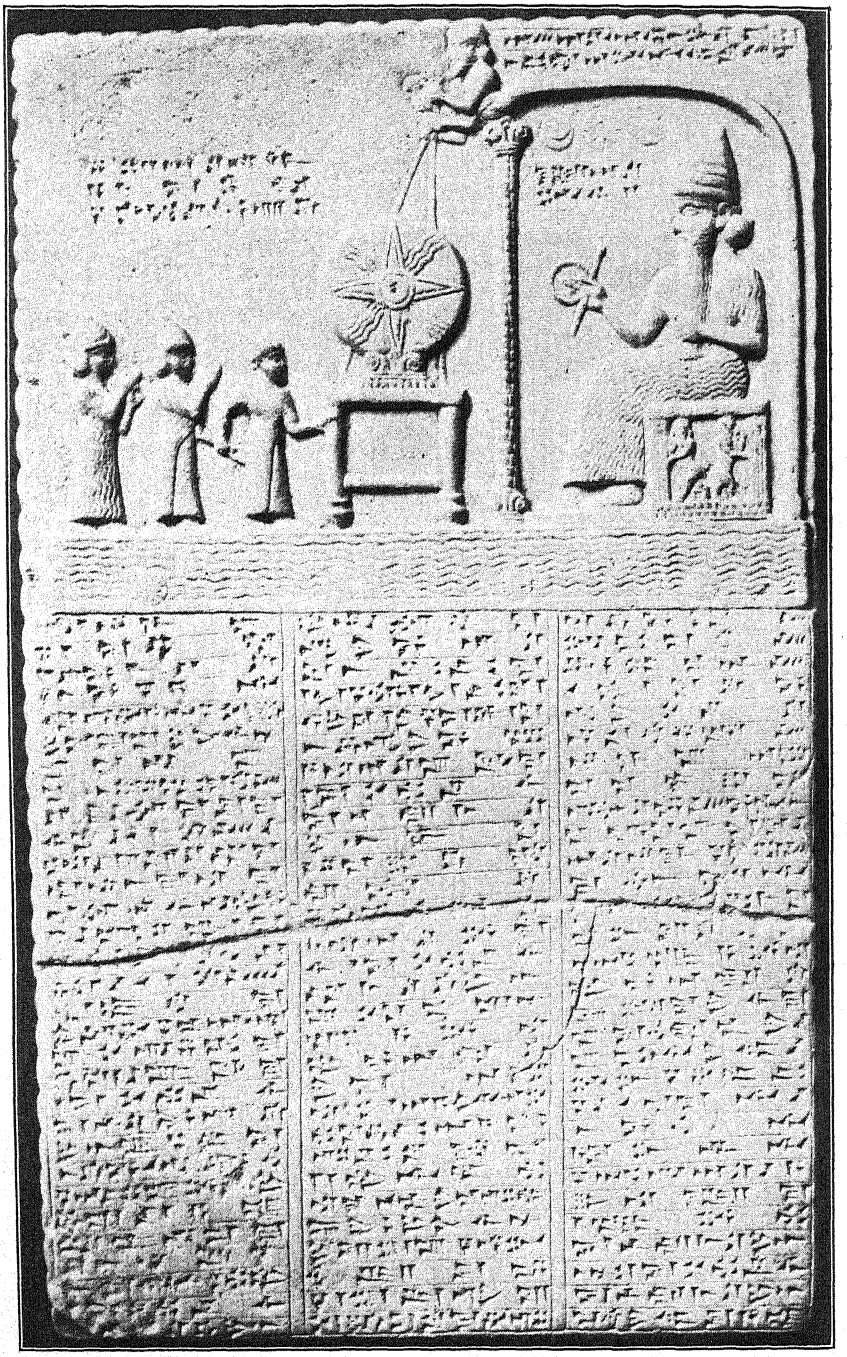


STATUE OF GUDEA SEATED ON JOINED STOOL. MESOPOTAMIA
Cast from original in the Louvre, Paris. Cat. No. 154438.

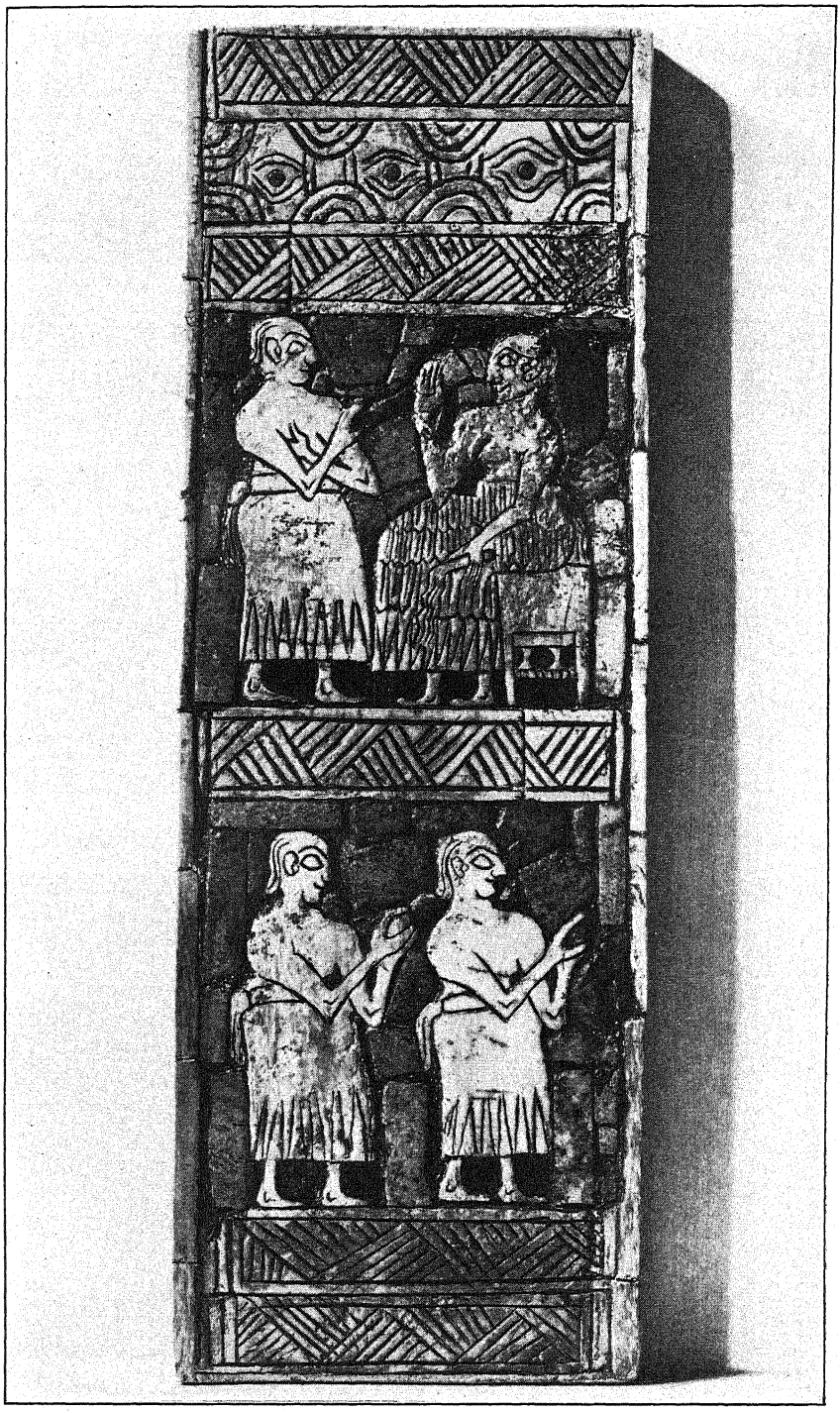


SCULPTURED SCENE ON STELE OF HAMMURABI SHOWING SEAT OF SUN GOD. MESOPOTAMIA

Cast from original in the Louvre, Paris. Cat. No. 229758.



VOTIVE TABLET OF THE SUN GOD SHOWING SEAT. SIPPUR, MESOPOTAMIA
Cast from original in the British Museum. Cat. No. 229672.



Courtesy of the University Museum, Philadelphia, Pa.

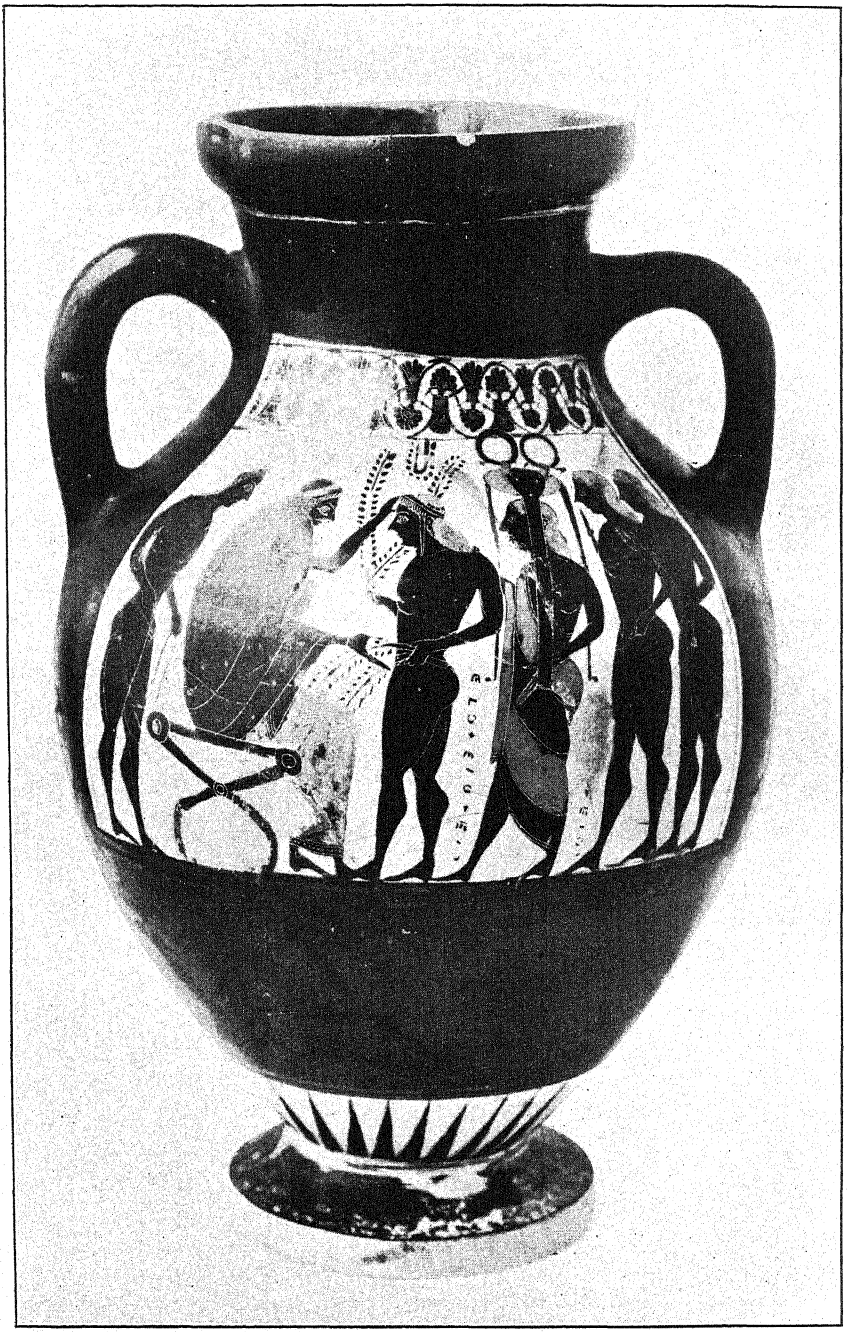
TABLET SHOWING SEATED FIGURE, UR, MESOPOTAMIA, 2700 B. C.



APHRODITE. TANAGRA, BOETIA, GREECE
Cat. No. 154724. Cast from original in the Berlin Museum.




CHAIR OF DIONYSOS, ATHENS, GREECE
From a cast in the British Museum.



VASE WITH SCENE OF AWARDING A PRIZE TO A VICTORIOUS ATHLETE

To left a figure seated on a folding metal chair. Orvieto, Italy, 600 B. C. Cat. No. 136415.

# ASPECTS OF ABORIGINAL DECORATIVE ART IN AMERICA BASED ON SPECIMENS IN THE UNITED STATES NATIONAL MUSEUM

By HERBERT W. KRIEGER
*United States National Museum*

[With 37 plates]

*Author's note.*—The available data regarding primitive art are encyclopedic in scope, but are not always readily accessible. In a brief article covering continental America, the barest of mention is made of several styles of decorative and representative art. New data are offered for consideration along with facts that are well known, while principles of primitive design are treated from a geographic point of view, considering tribal groups as they existed before their disruption after contact with the white race.

## STYLE IN PRIMITIVE DECORATIVE ART

*Geographic stability of design.*—In primitive society decorative designs appear as excrescences embellishing the arts and crafts. They constitute the hall mark of the primitive artisan. Characteristic forms of decorative design, like the technical structure or style of its artistic expression are local in their development. Art designs never wander far afield, and scarcely ever flourish when borrowed. Each of the more generally diffused elements of design as the triangle and zigzag or alternate spur, the spiral, the swastika or axial cross, and the meandered guilloche has a distinct local style which may never be mistaken when once one has become familiar with it in its local setting. Many examples of the ideosyncrasies of style might be cited. The designs of the Eskimo engraved on ivory tusks of the walrus or prehistoric mammoth and carvings in the round on wood by the Pacific Northwest Coast Indian tribes are characteristic each of a definite style area even to the point of differentiation of many subareas of design. Thus the Tlingit animal totem of southeast Alaska, though a realistic form of sculpture in wood, appears plain and crude when contrasted with the same totemic pattern as treated by the Haida, their British Columbian neighbors on the south. Again, the wood carving of the Maori of New Zealand with its repeated embellishment of engraved spirals may never be mistaken for decorative carvings of the Melanesians whose designs are likewise frequently characterized by the engraved

spiral. The same individuality of style may be seen in the peculiar body tattoo marks of the Marquesan Islanders, or in the metal crafts of Nigerian tribes, in woven textiles of the Haussa, or in pottery of the Ashanti of the Ivory and Gold coasts of West Africa.

There seems to be a key design peculiar to each distinctive art area that unlocks the secret of the origin of other designs from the same area. Frequently this key is merely a conventionalized form applied to any of the arts as textiles, wood carvings, pottery, or metal crafts. Examples are the cat or dog designs stamped on Peruvian textiles; the molded zoomorphic figurine heads on West Indian pottery; the engraved dog, leech, and leaf designs in Malaysia; the frigate bird design in Polynesia; or the double spiral and crocodile pattern of Melanesia. African metal work is distinctive; its various elements of form and design can not be mistaken for Malay metal work, each having its distinctive origin and development; for example, the modern brass and bronze casting of Benin in west central Africa was introduced by the Portuguese in the eighteenth century, and has a European flavor. In a similar way bronze castings and objects of iron from the Bronze and Iron Ages of prehistoric Europe are distinct from modern African metal work, while Malay metallurgy has Asiatic affiliations.

Application to the demands of the practical arts generally occupies civilized man to a far greater degree than it does the uncivilized. Somehow it seems that with the increased comfort and security characteristic of modern western civilization go augmented duties impinging on that portion of the universal culture complex that among all peoples passes under the name of artistry.

*Realism of Magdalenian art.*—The primitive artist works with the media with which he is most familiar. This may be seen in the cave art of the Magdalenian, whose serious occupation never exceeded that of the hunter. This artist, therefore, permitted free range to his artistic impulses to draw and to model animal life as he knew it. Game animals are most frequently represented. The horse and the red deer, also the lion and the hyena are depicted. The artists of the Old Stone Age produced realistic representations of bison, horse, and mammoth with a true appreciation of form. In plastic as in the graphic arts they modeled or depicted both animal and human forms. Sculpture in bone and in ivory display their ability to catch a pose. Life attitudes are perpetuated in their incised drawings. Even in the use of color there is a fine appreciation of values, particularly with regard to blends and shades.

*Culture change and decay of design.*—In the history of primitive decorative design there have been periods of progress and of retrogression. Retrogression in art forms appears to have followed

closely on the invention of weapons, tools, and implements serving to make for change in the practical arts, as hunting. Decadence in art forms formerly closely associated with arts of daily life followed the close of the Magdalenian culture period in Europe, as all attention apparently went into the shaping and production of the new accessories of material culture during the Azilian and early Neolithic, before the full blossoming of the New Stone Age both in the Old World and in the New.

With the invention of pottery in the Neolithic come new forms and with it new styles of graphic and decorative arts. Cave life had passed; the outlook upon the world had become that of the sedentary tillers of the soil. As the arts of the new era were mastered, new decorative designs hinged not upon geographical and occupational areas, but upon inventions in tool making and new forms of weapons and implements. In Europe there followed at an accelerated pace after the close of the New Stone Age, an age of Bronze, and later an age of Iron. In Europe, neither the Neolithic, the Bronze, nor the Iron Ages paused long enough to permit full flowering of crafts and arts into artistic forms. Geometrical designs alone survived, and if we are to judge from the unhappy modeling of the human figure in the Neolithic, realistic representations in Europe were lacking from each of the great periods following the Magdalenian. Save for ornaments almost all of our knowledge of Bronze Age design is derived from geometrical decorations on weapons such as knives, swords, and shields, and on implements. Even the pictographic art of Neolithic and post-Neolithic Europe is more crudely done than that dating back to the Magdalenian.

*What is primitive art?*—Primitive art as usually understood, however, is the product of geographic areas and of peoples who have for some reason not shared in the technical development centering about metallurgy in Europe. Other great metallurgical centers, as southeastern Asia and central Africa, developed art styles more commensurate with local developments in culture generally and were not disturbed by the early organized diffusion of western trait complexes.

When man attempts to represent objects of nature through the graphic arts of drawing, engraving, or painting, he is confronted with the problem of showing 3-dimensional objects on 2-dimensional surfaces. Primitive peoples solve this problem in a manner different from ours. Perspective is utilized by the civilized artist to give a visual presentation of the object as it appears to us in photography. The primitive artist realized that such a view must exclude from vision certain features essential for its recognition,

the eye, for instance, when the individual is seen from the back. Primitive art puts the eye in the picture regardless of its misplaced position and a pictograph gives way among the uncivilized to an ideographic presentation of essential features regardless of relative position. Profile views with both eyes showing or distortion of features to bring them into the picture are thus characteristic of primitive design.

Art styles, while products of cultural change, are in the main geographic. With many characteristics in common, areas in primitive art are recognizable. Thus South American and West Indian Arawak delineation of the human body is in the form of a triangle with the point downward, or in the form of a rectangle, the two descending lines of the triangle or rectangle being continued as legs, while the horizontal line at the top represents the shoulder line and is continued outward to represent the arms. In other areas the human body is often represented by a curved line which is open below and terminates in the legs and feet. The Eskimo silhouette shows only the outline of the figure depicted, but a realistic impression is conveyed nevertheless. The Indian artist of the American Pacific coast filled in details of a realistic nature in a distinctly modern manner.

*Symmetry.*—Body decoration in the form of tattooing, painting, and cicatrization takes on a peculiar local style which may be distinguished when analyzed according to the principles of form in art. The symmetrical arrangement of lines whether etched, tattooed, or painted is frequently the key. The Andaman Islanders and other Oceanic peoples decorate their bodies with symmetrical patterns; Australian boomerangs, churingas, and message sticks have symmetrically incised or painted designs. Symmetry in beadwork in America and Malaysia may also be noted. Even the Fuegians of South America understand symmetry in body decoration.

It is strange that among primitive peoples the lower forms of decorative art follow certain principles or elements in art design which are violated when once this primitive people has reached the stage of pottery manufacture. Symmetry in pottery design is not obtainable without the aid of a potter's wheel, which was never invented in any of the pottery-making areas of America or Oceania. The corrugated effect produced by the pueblo potter by means of thumbprints on the yet plastic coils of clay represents one type of pueblo design that is symmetrical. Bilaterally applied zoomorphic figurine heads on earthenware bowls of the eastern United States and the West Indies are other examples of the balancing of unsymmetrical pottery vessels through decorative embellishment. Bannerstones of the Indians of Pennsylvania have symmetrical bird or wing shapes. Vertical

symmetry may also be observed in Melanesian shields or in their designs on paddles and arrows, also on Polynesian dressing boxes of carved wood. Decorations of Melanesian houses have a rhythmic repetition of design motive. Banded patterns on bamboo, although differing one from another, are symmetrical in themselves and are repeated at rhythmic intervals giving a pleasing effect for the pattern as a whole. The omission, inversion, and distortion of pattern is carried out with almost mathematical precision. In Peruvian art on textiles, stamped blocks each incorporating a conventionalized life form of a cat or fish, for example, are repeated at regular intervals. Perhaps the simplest form of this rhythmic repetition pertains to brasses, bronzes, and iron objects from Malay and other oriental metal-work centers. Figures carved in the round, although produced by the Maori, the Melanesian, the African, the Haida of the Pacific northwest coast, the Aztec, the Eskimo, and the prehistoric West Indian Arawak, yet are sufficiently distinctive to become a key or index to the art of a geographic design area. In carving in the round, certain subsidiary principles arbitrary in their nature lead up to differences in their execution. The element of grotesqueness, frequently misunderstood, enters into the designs of each of the areas just mentioned so far as carvings in the round are considered. The omission of parts, the repetition of others, the misplacement to fit the media on which the design is applied—all these principles are well understood by the primitive wood carver; yet for each there is a difference in style.

*Tools.*—Tools used in executing art motives frequently effect a difference in the finished product, in other words, in style. The North American Indian uses a knife having a single-curved cutting edge while the African uses a straight double-edged knife. Not only in tools do we see a cause for the development of different art styles, even when applied to the same element of design such as the spiral, but in the manner, in which they are used do we find a considerable difference in the end results. This may be illustrated through the use of hammers whether held in the hand or attached to a handle. Cultural habits complicate the explanation of styles in art still further. Squatting tribes, for example, naturally do not develop artistically embellished stools or seats. A development of art in hair coiffures naturally leads to the invention and ultimate artistic embellishment of a neck rest. This we see at its best in Africa and in Japan. Development of tools in the form of molds, stamps, dies, patterns, drills, and bellows are but a few that might be named as having made possible the progress of design.

*Rhythm.*—The use of some one feature or detail repeatedly to express entirely different ideas is perhaps seen to best advantage in the repeated use of the eye motive by the Pacific northwest coast

Indian tribes. Other peoples also make repeated use of the eye motive. However, it remains an eye with them even when repeatedly used in a meander or scrolled design. In northwest coast Indian designs, however, the eye may represent joints, such as the elbow or the knee; it may represent the arm or leg, simply standing as a part for the whole; or it may represent the entire animal in conjunction with one or two other conventionalized features. The incised circle and dot, or nucleated circle in flat relief occurs widely in North and South America, but is used in a different way among different tribes. The Eskimo and the tribes of the upper plateau apparently use it in a purely decorative way without any symbolical or representative value. On pottery from South America and the West Indies, the circle and dot element becomes the eye, or it may stand for some particular kind of eye and thus represent a bird or a snake or the entire reptilian family.

*Art areas.*—The character of decorative primitive art is capable of geographic treatment. Art of a given kind characterizes a given region, with borders sometimes fairly definite, sometimes merging into the art designs and motives of adjoining regions by minute degrees of transition. Each tribe has art not exactly duplicated by that of any other. Even isolated villages within the tribal area develop marked divergences in design clearly intelligible to those who know.

Art areas, however, usually include several tribes occupying a geographical unit. The Eskimo constitute an art area, also a culture area, although they are not a single tribe. Linguistically the entire Arctic is a single area in the sense that the language spoken by an Eskimo in Canada may be understood by a north Siberian aborigine even though not an Eskimo. In ceramic and other art developments cropping out of a perfected pottery technique, we find eastern Siouan, Muskhogean, Caddoan, Timucuan, Calusan, and other tribal stocks sharing one art area, connected with West Indian and northern Colombian tribal designs. Likewise in the wooded sections of the Great Lakes and of the upper Mississippi Valley we may speak of a great art area shared by diverse linguistic and tribal stocks.

The general use of the swastika or almost all symbolism in the form of variants of the cross has a different application, and different meanings attached as we proceed from country to country and tribe to tribe. The use of the spiral is so widespread as to be of no significance in itself, although the technic employed in its execution may betray the maker. The spiral, common alike to painted designs on pueblo pottery in the Southwest and to etched designs on bamboo or wood in Polynesia or in lower Melanesia, can everywhere in the three areas be distinguished as to the maker by the crudity or excellence of workmanship. The spiral and associated double-curve

design representing originally zoomorphic forms, as the horns of the water buffalo in Celebes or the frigate bird in Polynesia, are almost mechanically perfect when incised on bamboo or gourds in western Polynesia. The spiral is crudely done in Melanesia and New Guinea. Not only are individual designs poorly or well done in one area, but all of the designs share alike and take their cue from the quality of the key design. We may thus speak of the excellence or of the crudity of design as characteristic of art areas.

The discrepancies observable between a similar art design of one tribe and that of another, and between one culture area and that of another show that designs and motives become devitalized as they travel from area to area. Designs like the cross and the swastika originated in more than one area, and have traveled no great distances.

*Design motivation.*—Types of art are recognizable by their predominant motives. Realism in Magdalenian and early Mediterranean art has been mentioned. Although realism enters into the designs of several geographical art areas, there are peculiarities characteristic of each of the areas. Dominance of a pattern of a similar nature in distinct or widely separated geographic areas, such as the "archaic" forms of human and animal figurines modeled in earthenware, found alike in the Valley of Mexico, and in South America, has mistakenly led to the assumption that the areas were directly related. Similarity in embellishment of an artistic nature is often accompanied, however, by structural differences in the object on which the artistic embellishment appears. Differences in symbolism or use may accompany similar artistic devices and designs. How many meanings, for instance, have not been read into forms of the cross or swastika?

Geometrical motives predominate where the designs are associated with basketry, or beads, or woven objects generally. It is a question whether their appearance on other materials, such as shell, wood, and other media, may be ascribed to the exigencies of a weaver's technic, when, as is the case in the art of Plains tribes, where weaving of textiles is not practiced, triangular and other painted devices are applied on rawhide boxes and pouches.

It is but recently in the history of our own western art that we have been freed from the tendencies to add features deemed essential but which were not conveyed by a photographic impression, which is but a momentary one. Thus, on the old pictorial maps we see not only lines of latitude, coast lines, and contour features, but ships at sea, dragons of the deep, and perhaps other objects designed to teach a moral lesson. A succession of impressions were placed in juxtaposition.

In painting we wish to see permanent colors, expressing ideas and idealizations, not impressions of the moment. Thus the contrast between photography and what we consider fundamental appears even in modern civilized art, although civilized style of presentation of such permanent features is far more sophisticated, and often more pleasing, than is the case with primitive art.

Conventionalism in primitive art need not be unrealistic; when possible, as in clay modeling or in wood carving, realistic portraiture is quite commonly found along with conventional or grotesque designs.

Modern Malayan art, for example, ranges far superior to prehistoric European achievement. It was only with the coming of Grecian influence to northern Europe that art forms developed there beyond the initial crude stage of the later Stone Age.

## MASKS

The primary association of the mask is with serious religious practices rather than with decorative art. With this, however, is combined the semireligious masked dance. The use of death masks in aboriginal America is perhaps limited to that section of the western highlands both of North and South America where the use of the mask itself had reached its greatest development. The mask was used in ancient Peru and the false head or mask is a common accessory with Peruvian mummies.

Contrasting with the false head on mummy bundles there appears in the lowland region of South America a form of dance mask. Its use is quite extensive as far north as the valley of the Orinoco River. In Mexico and in Central America the use of the mask apparently was general. The mosaic mask of the Aztec is a wooden mask which was overlaid with designs built up with small particles of turquoise. The stone temples in Mayan territory show in low relief profiles of priests wearing masks. Sometimes these temples have panels of plumed warriors and priests in low relief.

In the United States many tribes were apparently not addicted to the use of the mask. In the Northeast were the Iroquois, who were specialists in the manufacture and use of masks carved from single blocks of wood. Such masks were grotesque, with lips protruding, nose at tilt, and eye sockets cavernous. These faces represent mythical creatures essentially human. In the more totemic tribes the representations on masks are of animals, birds, and monsters of various descriptions. Between these two extremes we find many tribes, both east of the Mississippi and on the Western plains, among whom masks were in vogue. East of the Mississippi, the Cherokee, Chippewa, Delaware, Choctaw, and Seminole used

carved wooden masks. The tribes of the Pacific northwest coast, however, reached the highest development in mask carving.

In Micronesia and Melanesia numerous wooden masks were fashioned culminating in the masquerade costume of the Papuans of New Guinea. The Malay peoples developed the marionette rather than the mask, although there are certain traces of the primitive mask in central Celebes and Borneo. In Siam and Java, and on up into the continental hinterland of Eastern Asia, the elaborate demon and devil mask is everywhere present. The demon mask of the Tibetans is the most striking example of this sort. In structure the masks are simple where the ceremony is simple; where the ritual is more elaborate the masks are also complex.

In structure the Tibetan mask, in a way, is reminiscent of the mosaic masks of Mexico. Such casual resemblance, however, must be ascribed to the natural limitation of the mask rather than to an actual cultural contact or to a diffusion of this form of mask.

Judge J. G. Swan, one of the earliest students of northwest coast Indian lore, describes a ceremony which he witnessed and gives some information regarding the structure of the wooden mask of the northwest coast Indian. "Some are very ingeniously executed, having the eyes and lower jaw movable by means of a string so the performer can make the eyes roll about and the jaws gnash together with a fearful clatter. As these masks are kept strictly concealed until the time of the performances and as they are generally produced at night, they are viewed with awe by the spectators, and certainly the scene in one of these lodges dimly lighted by the fires which show the faces of the assembled spectators and illuminate the performers, presents a most weird and savage spectacle when the masked dancers issue forth from behind a screen of mats and go through their barbarous pantomimes. The Indians themselves, even accustomed as they are to masks, feel very much afraid of them, and a white man viewing the scene for the first time can only liken it to a carnival of demons."

Masks are not always identical in size with the human head or the head of the animal they are supposed to represent. They may be modeled in miniature, or they may be grotesquely enlarged. The stone and bone images worn on their forehead by the West Indian Arawak, also the carved whalebone or horn mask worn on the brow of the Shaman of the Pacific northwest coast Indian tribes, are diminutive examples. Some of the largest and most grotesque masks known come from widely separated areas. From central New Guinea comes the demon dancing mask, which not only covers the entire body of the dancer, but projects 10 to 15 feet above the bearer's head. Bird masks from the northwest coast are frequently large

enough to completely hide the operator. The human form assumed at will by all animate creatures is often represented in compound masks just beneath the animal's snout or beak. Often the animal mask is fitted as an outer false face covering the inner mask of human features. During a ceremony the outer mask is made to open up and reveal the inner face.

Formerly among most primitive peoples the mask was more or less of a personal possession of the shaman or medicine man. Only he could make the masks. Later, anyone might make or use them at will. Still later in our own civilization masks are a staple object of trade, having first lost most of their original significance. Some of the reasons given by the shaman for assuming the spirit of the animal, figuratively speaking, and for donning the features of the animal itself in the form of a mask, are to cure disease, forecast success or lack of success during the coming hunting or fishing season, to ward off danger from enemies, to supplicate the gods for rain to break a drought, to insure production and plentiful supplies. They are always intimately associated with fertility rites. In other words, the use of the mask originated as a purely selfish method of getting the properties of mythical and actual creatures to aid the individual. This is best typified among the Jivaro Indians of Ecuador. A warrior takes possession of his enemy's soul and becomes endowed with all of his strength by the simple process of successfully cutting off the enemy's head. It is then carried suspended from the belt and is a great aid to the Jivaro warrior. A similar belief motivates the Ifugao of Luzon when he goes on a head-hunting expedition.

As the material of which masks are usually made is limited to certain objects such as wood, basketry, bark, hair, or woven fabrics, generally, there appears to be a remarkable similarity in the masks of certain widely separated peoples. Thus the wooden mask of the western Eskimo is practically identical with the wooden mask of the Melanesians of New Ireland, a remote island in the South Pacific. Or again, a typical wooden mask from Java resembles very much the earthenware masks from western China. The Iroquois Indian mask is very much like that of the Cherokee and other Indian tribes of the Southeastern States, which, in turn, resembles those of the Alaskan Eskimo. Perhaps the closest resemblance is between peoples whose territory joins, as western Eskimo and northwest coast Indians, Melanesians and Polynesians. Thus the masks made by the Eskimo of the western Alaskan coast are copied by the Indians of the Yukon Valley. In a collection of 30 masks from Anvik, Alaska, a Tinne village perhaps 50 miles from the nearest Eskimo habitation, identity with western Eskimo masks in form, structure, and use is striking. Not only are the different masks representing different animals iden-

tical in name, but their detailed ceremonial use corresponds. These masks are used in ceremonies having to do with ushering in the hunting or the fishing season. It is sincerely believed by the Eskimo, and also by the Tinne on the Yukon, that proper ceremonies insure success in their economic undertakings. The celebration in which animals masks play an important part is always accompanied by a feast, popularly referred to as a potlatch, a term that originated far to the south among the Tlingit of southeast Alaska.

Among primitive peoples generally, the relation of animals with humans is based more or less on magic. Animals are supposedly gifted with magic powers of assuming human forms at will, of performing supernatural acts, and generally conducting themselves so as to defy the laws of nature. Therefore they must be propitiated, especially during crises in human life.

It seems that the bear, along with the raven and the coyote, are about on a par with the fox and the bear in European folk lore. These animals have supernatural powers; they are sly, they are tricksters, and at the same time they are culture heroes. The analogy between animal folk lore of Europeans and primitive peoples generally is almost startling.

A typical mask ceremony of the Yukon Indians is known as the "feast of animal souls." Its object is to assure success in hunting, and it is therefore celebrated in midwinter when the hunting season is best. Representations of the animals are carved on the ends of sticks which are stuck up at various spots in the community gathering place or kashime. Inflated bladders of as many different kinds of game animals as possible are contributed by the different families of the community. These are hung on a cord stretched across the kashime and the cord is shaken, causing the bladders to rattle. During the progress of the feast everyone must be reverent in his behavior, taking care to step softly in entering the kashime, and taking their places without noise or unseemly behavior. There is a succession of songs illustrating animal stories and legends. Boys representing the various families of the community are dressed in their furs with ornaments of wolf tails and wolf heads. A form of ice cream is then brought into the kashime in great bowls; on each bowl are stuck small models of deadfalls and other objects having to do with the hunt. The ceremonial eating of ice cream is observed in strict silence, even the whisper of a child being subject to severe reprimand. All of the animal mask feasts or ceremonies of the Tinne are very carefully rehearsed even to the waving of the feather plumes and the beating of drums. It is at the same time both pleasing and ludicrous to observe the graceful movements of the dancers who during rehearsals are encumbered with their babies and their

heavy out-of-door clothing. The ceremonial preparation and eating of ice cream is a trait extending from one end of the Tinne territory to the other. "Ice cream" is a concoction of bear fat, fish oil, preferably deer fat, blueberries or other berries, ceremonially stirred with the hand and arm bared to the elbow, during which time not a soul in the assembled throng is permitted to speak. Snow is slowly mixed with the other ingredients until the whole assumes the creamy pinkness of ice cream. When deer fat is used the preparation is edible enough, but with the addition of rancid oils and fats, more or less putrified, the concoction becomes unpalatable to the uninitiated. All night long stories are told about the hawk, the deer, and other animals, the women gladly sharing in the labor of making the ice cream so that their husbands shall have success in hunting.

The wearing of a mask is the usual method of impersonating the animal counterpart of a mythical human-animal being. When the American Indian impersonates a buffalo or a bear he puts the skin of the head over his own head and looks out through the eye holes. The effect is heightened by having the whole skin falling over the shoulders of the wearer and down the back. When a wooden image of a bear head is carved, the northwest coast Indian impersonates the bear and skillfully increases the illusion by growling and walking about bear fashion.

The antiquity of the animal dance is evidenced by many etchings and paintings on rocks of cave walls and of cliffs, such an important ceremonial as the Hopi snake dance, which is an ancient prayer for rain, being etched in detail on rock cliffs near Flagstaff, Ariz. The so-called Katchina mask occurs as a rock etching or painting throughout a wide area of the Southwest.

Most of the masks used by primitive peoples depend upon the environment for the material of which they are shaped. Thus the West Indian Arawak developed a culture in stone not native to their ancestral home in the forested lowlands of South America. This art culminated in the stone maskettes of Porto Rico and Santo Domingo. Similarly we may refer to the high development of wood carving among the tribes of the Pacific Northwest coast region. Reaching its highest development somewhere in southeast Alaska or British Columbia, this extensive art area extended as far north as the Arctic coast of Alaska and as far south as central California. Throughout this entire area the use of masks prevailed. Another extensive area in the development of masks was ancient Mexico. Here, however, as in the West Indies, we again find a development of sculptured forms in stone. In the Old World—that is, in China, India, and in the outlying districts of Hindu culture—masks play an important part even to-day. The use of earthenware and of leather in the shaping of masks is characteristic of this area. Here

we find a close resemblance in the leather puppets and dance figurines used in Java, Siam, Burma, Ceylon, Japan, and China.

Occasionally the Indian or the primitive Malayan, the Australian, or the African did not resort to masks but daubed his face with colored clay. Perhaps the greatest caricature of a masked human being is the Australian who has ceremonially daubed his face and body with ochres and clays in readiness for his very serious ceremonies or dances. Tribes living in regions subjected to great drought have developed a lore of animal life in the desert. The lowly Bushman and the primitive Australian have not advanced beyond the mimicry of animal sounds and actions familiar to them. An example of this is the dance of native Australian women imitating the jumping of the kangaroo.

## DECORATIVE ART OF THE ESKIMO AND INDIAN TRIBES OF THE PACIFIC NORTHWEST COAST

*Eskimo design.*—The engraved and carved objects of Eskimoan decorative art, characterized by the extensive use of ivory materials, has been likened to the art of the Magdalenian culture stage of central and southern Europe. The answer apparently is that, due to the Arctic environment it could not very well be otherwise. We do know, however, that the decorative art of the western Eskimo merges into that of the Pacific northwest coast Indian tribes. This may at once be noted in the realism of animal and human figurine carvings in wood and ivory in the two adjoining areas. Masks are a characteristic feature of Eskimo art as also of the northwest Pacific coast. The sculpturing of human features in wood, stone, bone, and ivory links up Eskimo art with a larger Pacific coast art area extending south as far as San Francisco Bay and central California. Representation of totem animals is also characteristic of the two areas. This representation is in part realistic and in part symbolic. Incised designs on wood, bone, and walrus or fossil mammoth ivory characterize similarly the art of the western Eskimo and of tribes of eastern Siberia. Feather decorations on hoods or coats, also embroidery work in border designs utilizing the hair of the seal are noteworthy.

The earlier geometric art of the Eskimo of Alaska is an offshoot of the boreal design area of northern and eastern Canada. The curvilinear designs engraved on bone and ivory are generally of the double spiral type of engraved and embroidered designs common to Indian tribes from the Naskapi of Labrador to the Dene of the valley of the Mackenzie. The design is not discontinued there but may be traced in beaded moccasin designs of the Tinne of the Yukon Valley westward across Bering Strait to the Amur River peoples of Siberia

where the design is perpetuated in embroidery alone, engraving becoming less common as the distance from the sea and the source of suitable material such as walrus ivory is diminished. There is a trace of the spiral and double curve to be found also among the wood carving tribes of the Pacific northwest coast, where it vanishes before the more powerful zoomorphic totemic design patterns and the plastic art of the Pacific coast area characterized by sculptures in wood. The realism of Eskimo silhouette engraving is noteworthy in that its technic remains simple. The ivory tusk having first been softened by immersing in urine, a base line is engraved lengthwise of the tusk. Outlines of animal forms, of landscape scenes in silhouette, of huts, canoes, and humans in profile are lightly etched. The outlines are filled in with cross hachure, blackened with dirt and grease, the whole picture representing a scene from the daily life of Arctic America. The figures give a sense of life and mobility.

*Wood carvings in the round.*—Carving and modeling in the round are peculiarly the achievements of the north Pacific coast and Eskimo tribes. Carving first appears in northern California and becomes more prolific in Oregon, Washington, and British Columbia, the Haida of the Queen Charlotte Islands and the Tlingit of southeast Alaska being the most adept carvers in wood and horn. Great totem poles and house columns are peculiar only to a small area of British Columbia and southeastern Alaska, while the exquisitely carved small horn spoons, images, and countless types of carved wooden objects appear from California to Point Barrow. Wood becomes scarce and is replaced with ivory north of British Columbia, and ivory carving begins with the Tlingit in southeastern Alaska and reaches its highest artistic development at the hands of the Eskimo on the bleak, barren coast of northwest Alaska. Along the eastern stretches of the Arctic in the homes of the central and eastern Eskimo their typical arts become marginal and artistic carving is less characteristic.

*Decorative art in relief.*—Relief carving upon the outside of wooden bowls results from an attempt to carry around the walls of the vessel definite designs of animals or men in such a way that the body of the bowl becomes also the body of the creature whose features appear carved on the outer wall surface. When a flat surface is decorated, the whole figure is spread out upon it. Sometimes designs of totemic animals are merely laid out in color and become thus more conventionalized. Indian tribes of British Columbia and of southeast Alaska practice their decorative art in a more intensive way as it is, in part, their expression of beliefs concerning family ancestors and culture traditions. North of the Tlingit and south

of the Nootka, of Vancouver Island, vessels may still be carved in the lifelike forms of animals, but are there devoid of relief ornamentation.

A textile center is located among the Salish tribes of inland Washington and British Columbia. Small geometric figures in colored yarns woven in a twined technic as in the basketry of the Haida and Tlingit make up a decorative pattern resembling the quilled woven bands of the Dene of the adjacent caribou area. The Chilkat blanket, woven by the northern coast Tlingit is decorated more in harmony with inland designs. Weaving of complex designs in twined blankets from patterns painted on wood are characteristic of Chilkat textile art. In fact, the weaving of goat's and dog's hair into blankets or robes with decorative design in color not only rivals the products of the Navaho and aboriginal Mexican looms, but hints at ancient connections with the weaving technic of the south.

In the National Museum exhibit of Tlingit and Haida costumes are large ceremonial blankets of goat's hair such as is being woven in the large Chilkat group case; robes of tanned deer skin bordered with quilled fringe and superb decoration in color; splendidly painted dance aprons trimmed with fur and fringed with deer hoof tinklers; and a woven dance apron trimmed with puffin beaks.

The house architecture, sculpture in wood, horn, slate, and the wood carver's arts of the northwest coast tribes have aroused wonder and admiration from the time of their discovery by the Russian explorer Bering, who first landed at what is now called Sitka, Alaska, in 1741. The earliest account of their peculiar arts dates back to descriptions written by Captain Cook in 1778. No mention is made by him of ever having observed totem poles, although his artist illustrates a house interior showing the great interior house posts with their carved totemic crests.

*Totemic forms and totem poles.*—Nowhere else in the world may one find a similar type of art. It represents for the most part the carved figures of animal forms, usually of well-known animals, such as the beaver, bear, killer-whale, shark, hawk, eagle, and raven, but also of mythical creatures such as the thunderbird, which makes lightning by the flash of its eyes and thunder by the clapping of its wings.

These carved images find expression on the tall wooden totem poles, house posts, dugout canoes; in fact, on almost every object of daily use from a musical instrument to an artistically carved cooking pot of cedar wood. The designs are usually in low relief but are duplicated in paintings in native colors on house fronts, on boxes, and in textiles and basketry.

28095—31——35

The most striking objects on which the native lavishes his best artistic efforts are the tall columns of cedar wood familiarly known as totem poles, but which are really memorials, erected in honor of the maternal brother whose property the builder has inherited. These totem poles are carved from the hollowed trunks of the giant yellow cedar, and occupy the place of honor at the center of the gable end of the owner's house.

The origin of the arts of the northwest coast Indians has never been satisfactorily explained. It has been suggested that they may be ascribed to a recent Asiatic influence or to migration of peoples from the islands of the south Pacific Ocean, among whom the arts of wood-carving are well developed. The extremely mild and humid climate of the northwest coast affords perhaps a better clue. At Ketchikan, near the southern boundary of southeast Alaska, the average annual number of rainy days reaches a total of 235. Dense forests of beautiful cedars supply materials for most of the native arts and crafts. The fondness of the Indians for working in wood becomes almost an obsession with them and finds expression, for example, in the long, seaworthy dugout canoes hollowed from a single cedar trunk. These boats are constructed with a high prow and stern, painted in black, green, or white colors, with representations of mythical and realistic animal forms. The birch-bark canoe of the northern interior tribes of Canada, or the skin-covered boat of the Alaskan Eskimo, is unknown to them. In a similar manner do the northwest coast Indians differ in almost every particular phase of their daily life from inland Indian tribes of Alaska, British Columbia, and the State of Washington on the south.

The art of the northwest coast Indian is unusual in that the totem pole which he erects, is pleasing in itself, although not intended primarily to please but rather designed to impress the beholder with the owner's greatness or wealth or position in society, and to induce respect for himself as the heir of the family crest and totem, all of which are expressed on the pole, usually at the base, center, and top. The Indian has inherited the right to the crests and totems representing the traditional animal protector of his uncle or mother's brother, together with his mother's family or clan name and rank.

Totem pole art is almost entirely a representation of animals. These representations refer for the most part to the rôle played by certain animals as actors in native myths. To properly understand the carving one must know the story of the myth. Then, to make the totem pole art still more abstruse, the Indian artist has certain rules of procedure which obtain for him the desired results but which make the representation of animals unintelligible to us unless the rules are also known.

He adds certain parts which convention dictates; or he may simplify and represent only what are to him the essential animal parts.

The curved beak of the hawk is invariably represented as touching the mouth on the under side, while the thunderbird, which wears a cloud hat, has a larger beak. The raven has a long, straight beak, while that of the eagle is short and curved. Birds, even when they take human form, are to be recognized by a beak added to an otherwise human face.

The beaver usually has a stick in its mouth, which it holds between its paws. The large projecting incisor teeth and scaly flat tail are further characteristics. Certain mythical water monsters may take on a variety of forms. Animal representations have erect ears placed above the eyes, but are otherwise often difficult to distinguish from human figures. Stock objects or fillers-in occupying the spaces on the totem pole between the totemic crests are such minor animals as frogs and ground worms.

The bear is usually carved in a sitting position holding a stick between his paws while his tongue protrudes from his mouth.

The shark carvings may be recognized even when represented in human form by three parallel markings on the cheeks representing gill slits. The forehead rises in a triangular-shaped lobe, while the downward-curved mouth is drawn back exposing sharp triangular teeth. Other fish are distinguished by their fins. The killer whale is characterized by the prominent dorsal fin.

The most important thing in the life of the Indian is his crest or totem. Representations of this animal crest are placed on every conceivable object of daily use; they are even tattooed on his arms and body and are painted on his face. The inheritance of a proper kind of crest or totem determines an individual's chances for success and for a favorable standing in the community. As he inherits the crest or totemic animal protector from his mother's male relatives, he makes it his business to erect a memorial column to his maternal uncle as soon as he is financially able to do so. This totem pole has carved on it, as mentioned before, the symbolical and often distorted or simplified animal figures representing his inherited family glory or experience. It may be only after years of saving and effort that an Indian is able to erect the column which firmly establishes his place in the estimation of his fellows.

## INDIAN ART OF THE EASTERN WOODLANDS AND OF THE WESTERN PLAINS

*Design technic of eastern Indians.*—As compared with the numerous objects now housed in museums but originally collected among Indian tribes of the western plains there is little material

extant from Indian tribes of the eastern portions of the United States. In the case of the Virginia Indians, the only source of information is the meager description left by Capt. John Smith and a number of drawings, now preserved in the British Museum, made by the artist John White. There is likewise a scarcity of data regarding design motives of all of the eastern Indian tribes. Costumes and objects of dress now in the National Museum from Indian tribes formerly occupying the region east of the Mississippi River fill

Simple buckskin garments, coarsely woven cloaks embellished but one small exhibit case.

with turkey feathers and used only in colder weather, moccasins, and, in the case of the Gulf State tribes, leggings, fringed girdles, and feather-plumed turbans were characteristic objects of dress. Weaving of bast fiber of basswood and of the mulberry, also of yarn fashioned from buffalo hair is said to have been practiced in the Lower Mississippi Valley, where basketry still remains as a live weaving technic. Chitimacha basket weavers of Louisiana use spilt cane splints in natural straw and in dyed black and red colors. Mantles of turkey feathers were plaited in the Southeastern States, but were apparently devoid of any attempt at decorative design. Fringed buckskin garments, simple beaded designs on moccasins and belts, and farther north woven belts and sashes made on an upright frame, embroidered bags and pouches decorated with beadwork in floral designs, and also body painting and tattooing are forms of decorative art inferior to styles and types of ceramics from the same area. Subareas of ceramic art are numerous east of the Mississippi.

*The double-curve motive.*—Beads and quills are employed in eastern Algonkian designs but in a different manner from that of Plains tribes, resulting in a distinct type of design. Instead of rectangular textile embroidery or angular painted figures, the lines are curved and plantlike figures result. This design pattern, known as the double-curve motive, is really a double incomplete spiral. Resembling leaves, plants, and vines, the design is executed on birch bark or painted on skins. Painted coat borders of the Naskapi Indians of Labrador are a good example of this art, although the Montagnais, Micmac, Passamaquoddy, and Penobscot reached the same results through quill or moose hair embroideries, bark etching, and beadwork, while farther westward the same double-curve pattern has been adopted by the Cree, the Chippewa, Huron, Sauk and Fox, Menominee, Winnebago, and certain of the Plains tribes as the Blackfeet. The Iroquois and Delaware Indians, like the western tribes just mentioned, used beads and porcupine quills with which to embroider similar curvilinear designs.

Belts of wampum, bands of quill, and moose hair interwoven with bast fiber tend to the geometric. The double-curve motive does not work well in these materials. There appear to be some distinctions between the eastern and the western sections of this area. The Dene of the Mackenzie Valley of northern Canada weave rectilinear and curved bands of quill and moose hair; while the Chippewa of Wisconsin and the Menominee weave on a simple frame belts, bags, and mats incorporating geometric designs. Textiles are elsewhere practically nonexistent in the northeastern part of North America.

Drawing and etching on birchbark became such a highly developed art among tribes of the vicinity of the Great Lakes as to form a system of symbolic or mnemonic pictographic writing, along with a decided realistic tendency in beadwork, while in the East, freehand double-curve floral figures were embroidered or painted. The extreme floral character of some of the beadwork of the Chippewa has led many to regard the whole as a post-Columbian development. The wide distribution of the Cree and Montagnais, together with their very early intimate association with the French colonies, presents a favorable condition to rapid diffusion. Yet, their very characteristic double-curve art on bark and painted skins can not be attributed to Europeans whose trade stimulated the use of beads, while the influence of the old French missions in the Mississippi Valley and in Canada is not to be underestimated. There seems not the least reason to doubt that the very striking beaded flowers of the West are due to the influence of French mission fathers.

*Pictographic art.*—Representative art of the tribes of the region surrounding the Great Lakes and also of the Plains tribes, is expressed in picture writing. As decorative art the designs show a distinctive pattern and conventionalized pictographic devices. Paintings on muslin cloth supersede the older art of painting on tanned hides landscape scenes embodying horses, men, and hunting scenes where are shown buffalo. Horse stealing is also a favored theme for pictographic or representative decorative art. From the viewpoint of art styles, pictographic or, as we might call it, ideographic art, has not a high value. The engraved pictographic representations on rock cliffs similarly placed throughout many of the areas of primitive art in America and in Oceania have a motivation in representative art rather than in decorative design alone.

Decorative designs in color are characteristic of fewer areas and peoples than is their application of design in relief. Modeling and engraving are the early technics of decorative art. Decorative art of Plains tribes consists in the painting of geometric designs on saddlebags of rawhide, while the tribes of the Pacific northwest coast paint totemic zoomorphic forms on chests and boxes. The Eskimo

use black color as a filler in line cuts to bring out the sharpness in their silhouette designs. The same effect is obtained by Papuans and Melanesians through the use of white kaolin.

Limitations imposed on the primitive artist by the materials with which he works and the technic which he must employ are potent in shaping the style of art.

*Geometric art of the Plains tribes.*—Much of the decorative technic of the Plains tribes consists of bead embroidery, an outgrowth of the former widespread use of split quills of the porcupine. The most beautiful examples in the National Museum of the use of porcupine quills in embroidery are in the few remaining specimens of the Catlin collection obtained by George Catlin from several unidentified tribes in 1838. The decorative designs embroidered either in beads or with porcupine quills are geometric and consist of triangles and rectangles in varied arrangement of figures and colors. The use of the triangle has come to be a distinctive mark of the art technic of the Plains tribes. Sometimes this triangle is acute and again it is obtuse. When acute it is called a tipi design and frequently has extended bars reaching beyond the apex. The obtuse form has a rectangle inside recalling the stepped insert of the Pueblo tribes. Parallel lines of beadwork are interpreted as trails; breaks in the trail indicated by colored beads represent camping sites.

There are considerable tribal differences in the patterns embroidered as also in the painted designs applied for the most part to rawhide containers, as quivers, saddlebags or parfleches, work boxes, and the like. The Sioux are distinguished by their use of the entire field as a surface for applying the design. This is especially noticeable in the embroidered beaded patterns on moccasins, bags, and pipe bags. White beads or a cream-colored paint fill in the background, setting off the angular designs. The Arapaho, on the other hand, use several small stripes of color covering but a small portion of the whole area of the decorated object. The unique spurred acute triangle design of the Comanche is set off at the apex with curved hornlike volutes. Plains designs embroidered or painted are both realistic and abstract in their meaning. Purely animal forms are not painted on rawhide or embroidered in beadwork or quills. Geographical features as lakes, mountain passes, rivers, and trails are represented even to such details as trees, growing grass, and buffalo. To be sure, an interpretation is required to appreciate such realism, as buffalo, for instance, are represented by a series of dots boxed in a rectangular figure. A mountain pass is the angle between two bordering obtuse triangles.

The Blackfeet are unique in that they attach no symbolism to their designs which resemble those of the Sioux, Cheyenne, and Arapaho.

With the Sioux, the pictographic designs are symbolic and are applied by the men of the tribe, while the women care for the purely decorative embellishments. Complex designs are built up from rectangles, diamonds, triangles, and line patterns. They have names which they apply to the designs they make, but the names do not signify that the design represents the object named. For example, the turtle design does not look like a turtle and does not represent a turtle. This design is a common one and resembles rakes attached at right angles to one another by their handles where they are covered with a lozenge-shaped design. Undoubtedly several formerly symbolic devices have deteriorated, and are now applied simply because it is the style. Thus, the turtle device much simplified appears as a design embroidered on the back of a woman's dress, also on the front as a U-shaped semisacred device.

While on the Pacific coast realism tends to express itself in the delineation, modeling, or etching of human and animal figures, the art of the western plains is characterized by the employment of geometric design. Tribes occupying the plateau area beyond the Rocky Mountains and east of the Pacific coast tribes, occupy a middle position in which geometric designs predominate. Designs formerly embroidered with porcupine quills are, since the coming of the trader, now worked out in beads. Painted designs appear on rawhide shields, saddle bags, decorative skin and tipi covers, and on other materials of rawhide, while the quills of the porcupine are sewn on tanned skins in geometric patterns. Use of porcupine quills has not entirely given way to trade beads of glass, but the early quilled, small checker patterns as shown in collections made by Lewis and Clarke, by George Catlin, and by the early explorers generally have gone. Painted parfleche or saddle bags are still fashioned and decorated, and the ancient art has not entirely disappeared from the Plains and plateau tribes.

Tipi covers are decorated with realistic and symbolic designs such as stars or eagles. There is also incised work on wood.

The Sauk and Fox Indians, like the Plains tribes and the Pueblos follow definite patterns in decorating the walls of their rawhide vessels. Decoration of the several fields is planned on a yet unfolded piece of rawhide. Painted designs, although symmetrical, are lost when the rawhide box has been folded. The elements of the design, when not hidden by the folding process appear as acute triangles with oblique spurs, Maltese crosses, hourglass forms, lozenges, and isolated obtuse triangles.

*Symbolism.*—Symbolism includes abstract ideas as well as religious motives. Kroeber's study of Arapaho symbolism is important in arriving at a conception of what, in the mind of the primitive artist, is back of apparently simple geometrical patterns of

lines or triangles. Thus a stripe executed in colored beads on the uppers of a moccasin shows the destination of the traveler, while the beaded heel stripe indicates the place of departure. A white border represents snow, while transverse stripes across the instep represent hills and valleys. Triangles represent mountains. Sioux symbolism is almost identical. This was studied by Wissler. Large triangles in applied bead work represent tents; crossed patterns represent arrows or flight of arrows. The double triangle placed back to back with another set of two triangles forming a cross is a favorite Siouan pattern and represents conflict, perhaps between the two sets of triangles representing tents. Among the Arapaho, a white stripe with dots in it represents a buffalo trail; acute triangles are tents, while bordering obtuse triangles represent distant mountains, perhaps where dwell the buffalo. The sun shining on a mountain might be represented as the top segment of a triangle in yellow paint, while the middle or bottom appearing in red color represents the ground, and green grass growing on the slopes. A Shoshoni parfleche with a blue central rectangle represents an inclosure surrounded by an enemy which is represented in red or green outer rectangles. Embroideries in beadwork, and paintings on rawhide, the first on pouches, pipe bags, work bags, and awl cases, and the latter on quivers, work boxes, and saddle bags (parfleches), have no apparent distinction as to design.

Among the Arapaho a cross with scalloped ends represents a star. Many other designs resembling a cross also represent a star. The same designs when painted with different context may represent individuals. Kroeber shows how a diamond-shaped figure might be used to represent a turtle, a mountain, a star, an eye, a human being, and the navel, or a lake. A rectangle represents a hut, a mountain, a camp circle, a buffalo, or the earth.

A buffalo motive is treated by the Plains Indians in an interesting manner. A painting on the tanned surface of a buffalo, calf or doeskin is centered with a rectangular device with triangular extensions at the four opposite corners. Triangles are added oppositely at the ends and the representation is complete. This treatment is symbolic and signifies the want of more buffaloes for the chase.

### PICTOGRAPHIC AND DECORATIVE DESIGN OF THE NORTHERN AND SOUTHERN PLATEAU, AND OF THE PACIFIC SLOPE

Decorative designs of Indian tribes occupying the high lands west of the Rocky Mountains, and the Pacific slope south of the Columbia are of interest primarily because of the extreme contrast which they represent in the range of aboriginal culture. It has been noted that Indian tribes of the plateau region possess a culture type transitional between that of the Plains and of the Pacific northwest coast

tribes. This is not actually the case as they have absorbed only certain types of culture traits from the Plains tribes, and none at all from the Pacific coast group. In prehistoric times, before the introduction of the horse in the valley of the Columbia, plateau culture resembled that represented until quite recently by the Thompson River tribes of inland British Columbia. This culture then represented a single design area originally shared by Shoshonean tribes with the Basketmaker, Apache, and Navaho of New Mexico and Arizona on the south, and the Californian tribes of the west coast. Within historic times, Plains design motives, and design patterns have filtered in from the east, while in Arizona and New Mexico the developments leading up to the growth of sedentary agricultural life of the Pueblo Indians had long been under way. Here, as elsewhere in aboriginal America, were developed ceramic and textile arts without apparently any assistance or hindrance from without. The nomadic Navaho and Apache groups disjointedly learned from the Pueblos their arts, while the Californian tribes continued until historic times to pursue their unique basketry art. No suggestion has ever been advanced regarding the borrowing of this art, which permeates their entire culture complex, from cooking vessels to cradle beds. The twined basketry of the inland Salish is distinct in that it is intimately associated with weaving technic, which is not practiced by the California tribes. Aboriginal California, except for isolated culture influences coming from the north, offers an excellent example showing how a culture may grow in isolation, the key to decorative design being excellence in basketry technic.

Among the basket-making Apache of the Southwest, objects of tanned skin decorated with beadwork designs, represent an intrusion from the Plains area. Identity between the designs on Apache baskets and objects of skin is therefore unusual, the latter being borrowed from the Cheyenne or Comanche. Among the Plains tribes it was the men who painted robes, tipis, and other skin objects with realistic figures, while among the Shoshoni farther to the west, both beadwork and basketry were the work of women, who wove symbols into their art, although, like most of the Plains tribes, they did not decorate pottery.

Pictographs and petroglyphs are paintings and engraved designs occurring on the smooth surfaces of rocky cliffs and boulders. Explanation of the 60 or more elements of design has been attempted many times, but represents merely guesses. They represent, to be sure, objects and ideas with which other primitive artists of the tribe were acquainted. They do, however, give one a definite clue as to the tribe to which the individual belonged; it may be assumed that tribal art is always distinctive and characteristic.

*Similarity in basketry, pottery, and weaving design technic.*—There is an observable unity in designs on baskets from Utah and

other Rocky Mountain States and on earthenware vessels from Arizona and New Mexico. This is readily ascribable to the use of checkered and angular devices in the designs of both classes of aboriginal objects. To be sure, there is a greater freedom in the use of curved and symbolic or realistic designs on Pueblo earthenware, but fundamentally the designs belong to one area. Even the designs woven into the famous blankets of the Navajo fit into the type of design, which is fundamentally geometrical. It is interesting to note that the pottery technic under discussion is limited in its distribution, while the basketry technic is both ancient and more widely extended, reaching from one end of the western plateau country to the other. It is also interesting to note that the weaving technic of the Navajo is a comparatively recent acquisition, reputedly having been borrowed from the Pueblo Indians whose weaving technic apparently belongs with that of northern Mexico. In Navajo and in Pueblo weavings there is embodied a style of geometric art design such as might have been borrowed from basketry, but which might also have been developed independently. This design, as in basketry, is characterized by series of stepped rectangles and by diagonal series of small squares and transverse stripes. In the older fragments of Pueblo weavings, rescued from cliff dwellings, the designs are marginal or consist merely of stripes, the entire field being plain.

*Pueblo symbolism.*—As is well known, the representative as also the simply decorative patterns of the Pueblo Indians of Arizona and New Mexico are best expressed in painted designs on earthenware vessels. These are in part conventionalized and symbolize mythological and religious motives. The purely decorative earthenware designs are in part realistic and in part conventional. Repetition of a motive either geometrical, as a spiral meander, or realistic, as birds facing each other in inverted form, and with interlocking beaks are painted on the inner or outer walls of pottery bowls. The repeated use of the eye design in decorative or in symbolic representative art is reminiscent of other, unrelated areas. Boas calls attention to a Pueblo decorative design consisting of a triangle with rectangles attached or inclosed. This pattern occurs on the western plains among the Arapaho and other tribes each attaching a distinct meaning to the design. The Hopi Indians of Arizona substitute the semicircle for the triangle, and instead of spurs attach long lines in parallel to the base of the design. The semicircles according to the Pueblo Indians represent clouds, while the vertical lines represent rain. The Shoshoni, Arapaho, and other Plains tribes call the angle design a mountain or a mountain pass. The Pueblo apply the rain cloud design on earthenware as a painted figure or on wood as an altar painting.

Elaboration of mythological, religious, and symbolic lore into design pattern is characteristic of the Southwest. Representations are geometrical; motives are usually magical or symbolic. Designs on shields of rawhide, on cloth, woven basketry, and on pottery, are no less common than are images principally in the form of dolls cut from wood. Feather designs are associated with religious practices and are not purely decorative. Paintings in clay and on sand are also associated with ceremonialism. A borrowing from the ceremonial art of the Plains may be seen in a Pueblo painting representing a buffalo stretched out on a tanned doeskin. (Cat. No. 11317, U.S.N.M.) It was collected by W. F. Arny, governor of New Mexico in 1877. The art pattern is geometrical, being identical with a Comanche painting (Cat. No. 6975, U.S.N.M.) of a buffalo applied in the same geometrical pattern with lozenge-shaped head, diverging horns and a border design of triangles. The painting is in glue applied with a stick which rubs the glue into the skin, and when it hardens brings the design in relief. The painting is really an altar piece representing a prayer for more buffalo.

*Pueblo pottery.*—The repeated invention of pottery making in America is no longer open to question. There are, to be sure, certain universally diffused steps whereby the earthenware vessels are brought to a finished state, similar throughout the entire area of pottery manufacture in aboriginal America. Coiling of clay ribbons instead of gouging out of the solid mass of clay, for instance, is the prevailing method, and has been the prevailing method of pottery production throughout the Americas. For that matter coiling has been the prevalent method everywhere among primitive peoples with but few exceptions.

In the country of the Pueblo Indians, in Arizona and in New Mexico, the clay is collected from suitable beds and carried to the village. It is there worked by the potter into a powder, impurities removed and tempering materials such as crushed potsherds or crushed fragments of mineralized rock added to the powdered clay. The mass is then thoroughly mixed and pulverized, and water is added.

The bottom of the vessel is molded on a solid substance used as a foundation. This may be a basket fragment, or a fragment of modern crockery. Next are added to the rim of the base a coil or ribbon of clay, fashioned by rubbing between the open palms of the potter. Successive coils are fitted one above the other and are joined with the aid of wet fingers and improvised tools consisting of curved gourd fragments each cut to suit the particular curve of the walls desired in the vessel to be shaped. The drying process serves also as a test of the quality of the paste, as it will not crack while being dried if tempering is adequate. Next the vessel walls are moistened and scraped with bits of sharp stone to remove irregularities, and to

reduce portions of the walls to proper thickness. The thoroughly smoothed walls are now treated with a slip or several coats of a slip consisting of white, yellow, orange, or reddish shades of clay reduced with water to a thin paintlike mixture. The slip serves as a background for the painted designs to be later applied in colors. Some vessels are now burnished with a rounded stone in short rotating movements. Fat of sheep or some other form of grease is applied as lubricant for the process and as an aid in obtaining a luster.

The painting of symbolic or of merely decorative designs in colors is the most interesting stage in the manufacture of Pueblo pottery. Paint brushes of split yucca leaves from which a portion of the leaf has been removed leaving a straight edge for line work, are commonly used for applying the paint. Most of the colors are obtained from mineral ochres in shades of red and yellow, and in black which is obtained by boiling the juice of the bee plant (*Peritoma serrulatum*). The ochres are either used raw or are burned. The painting is altogether freehand but must follow definite patterns well known to all the women who make pottery and also to the men who occasionally make pottery vessels.

After the vessel has been satisfactorily painted the potter piles up several newly fashioned vessels in an inverted position and builds an oven around them. This consists of dried dung or split cedar wood completely covering the vessels to be burned. A hot fire is maintained for the greater portion of an hour when the firing has satisfied the potter.

In certain cases, when an undecorated ware is to be fired and a black color is desired, a smothered fire with plenty of smoke is maintained throughout the firing. Red slip under such conditions turns a brilliant black. After firing, the vessels are cleaned with a greasy rag.

The form and design of Pueblo pottery although differing from tribe to tribe and from period to period, yet is distinct from that of Mexican wares and entirely distinct from the pottery of the eastern United States. Perhaps the most distinctive feature about Pueblo pottery is the use of paints in conventional designs pertaining to local mythology. To a much lesser degree are life forms molded or luted on to the walls of the vessels or to the handles and lids of earthenware vessels. Rims are sometimes shaped into angular scallops and are never wavy or boat-shaped as in the eastern pottery area. Decorative design often takes the form of eccentric animal and human modelings; birds are modeled in more lifelike patterns. The painted paneling on the earthenware vessels of the Zuñi separates the wall space of earthenware vessels into several divisions on the neck and body. Designs painted on the neck space are repeated to produce a symmetrical balance. Neck designs consist of volutes

or double curves resembling those of the eastern woodlands area; also of triangles and lozenge-shaped figures, and of prayer-stick designs distorted to fit the space. On the body of the vessel appear in combination certain figures as that of a deer and a rosette representing a sunflower. There they are repeated in a manner showing an appreciation for the symmetrical disposition of space. There may be another encircling panel filled with an interlocking scroll of inverted or interlocking conventionalized birds. A series of three rectangular steps or terraces may be substituted for the deer, sunflower, and bird-design patterns.

## THE WEST INDIES, MEXICO, AND SOUTH AMERICA

When Columbus first encountered American natives on one of the Bahama Islands he met with the most northern of the South American tribes. The prehistoric inhabitants of the Bahama Islands were Arawaks who had followed the island chain northward from the Venezuelan coast. Their culture was a meager one, perhaps much more so on the part of the Bahamans than on the larger islands of Haiti and Cuba where stone carving and woodworking rivaled in excellence the various types of freehand modeling of life forms in earthenware.

The Indian tribes of northern Mexico are adept at the weavers art and embroider designs based in part on native and in part on Spanish patterns. Geometrical devices and animal forms essentially native combine with heraldic patterns. The conveying of ideas is at the bottom of much pictographic or representative art of Mexican tribes. This, however, does not lessen the value of the ornamentation.

*Mexican art area.*—Ancient Peru and ancient Mexico produced and maintained dense populations at various centers, but round about these centers were lesser populations occupying marginal positions. Among the Huichol Indians weaving incorporates designs having marked realistic tendencies. Modern textile art from the Rio Grande to Panama shares this train of realism in design. There is a general similarity to Peruvian conventionalization of its art designs. According to early Spanish authorities the Mayan peoples were the most expert weavers in New Spain. Contact with the Spanish altered to a certain extent the design but the old resemblance remains with the Andean highlands. Pottery likewise survives only through archeological studies, extensive collections revealing painted designs. Painted designs and modeling of embellishments in relief here take the place of mere pueblo designs. In the Panama area, including Costa Rica, and the Chiriqui district of Panama, we have complex designs of animal and reptilean forms

recalling textile and Peruvian art designs. Mayan textilelike designs for mosaic and stucco work are striking exceptions to the rule that realistic carving and design prevail.

*South American art areas.*—Aboriginal textiles from the Inca region of Peru have been preserved in great abundance in the rarefied dry climate of the Peruvian highlands. These show complex color designs producing realistic designs of men, birds, cats, fish in more or less conventionalized form, all with the geometrical basis of loom weaving.

There is a superior development of earthernware decoration incorporating life forms in jars representing persons, birds, monkeys, fishes, plants, as corn, potatoes, peanuts, gourds, and others. Decorations are in color and in incised work. In color the Nasca and Titicaca ware is superior to anything yet discovered in the New World. The painted designs upon this pottery are comparable to those upon cloth in their realistic tendencies. Certain fixed conventional forms appear both on pottery and cloth.

As we go out from Peru in both directions pottery decoration becomes inferior. Historical relations of this center with adjoining regions have not as yet been worked out.

This Andean highland culture spreading northward west of the Rocky Mountains and southward along the western slope of the Andean ranges is the true home of a most characteristic and the highest development of art form and design in the Western Hemisphere. There is no possibility of direct connection between this peculiar development and other art centers in Oceania or on any of the continental masses of the Old World.

The geographical center of this great American development is furthest removed from any possible contact with peoples from other continents, the only possible routes of entry into America being the Aleutian Islands south of the Bering Sea, and the islands of the Bering Sea itself, and the more scattered islands of the south Pacific. None of these were favorable routes for entry of ready made art complexes. The infiltration of peoples must have been painfully slow, perhaps occurring but once in the entire geographic history.

On the other hand one can not ignore certain parallelisms of development in the arts of tropical peoples of Oceania and South America. Similarly one can not ignore a certain parallelism between the high achievements of the Inca, the Aztec, and the Maya on the one hand, with the Egyptian and Asiatic cultures on the other. Another parallelism, that of cultural types, Melanesian and lowland South America might be placed alongside the observed parallelism between New Guinea, Maori, and north Pacific coast cultures. There is also something to be said for parallelism in African design with that of eastern America. Similarly one might point out more gen-

eralized parallelisms that prevail practically throughout the entire world where there can be no possibility of migration of peoples or even of the art designs themselves. The use of the spiral, in fact of all the elementary forms of incising, the many forms of simple crosshatch, etched or painted, the many symbols of motion widely known as swastika, and in weaving, the application of certain geometrical designs are found wherever a basket is woven or wherever a piece of cloth is produced. The widespread diffusion of geometrical designs on tapa cloth or on bark cloth are purely environmental in their distribution. In a similar way the beginnings of plastic art and of sculpturing in wood and in clay are distributed.

Hundreds of examples might be selected which first appear to show a culture connection. All these must be discarded as examples of pseudo-culture diffusion in that the very arts themselves, of weaving, of pottery making, of wood carving, and of many other crafts when perfected, lend themselves readily to a display of similar forms of surface finish and embellishments.

Such is the beginning of primitive art. Although widespread in its various presentations, it began in a thousand places when the primitive craftsman began to realize his power over material. As soon as he began to play with his technic he became a primitive artist as well as a primitive artisan.

## EXPLANATION OF PLATES

### PLATE 1

The god of the east wind, one of the disease-bearing gods of the Iroquois Indians, tribe of the Onondaga. Cat. No. 248702, U.S.N.M.

### PLATE 2

Wampum belts in the United States National Museum.

Top: Cat. No. 248744, U.S.N.M., Delaware Indians of Ontario, Canada. G. G. Heye collection. This belt resembles the famous Penn treaty belt delivered to William Penn at treaty of 1682 at Shackamaxon.

Middle: Cat. No. 165103, U.S.N.M. Iroquois Indians of Canada. W. N. Thompson collection.

Bottom: Cat. No. 201156, U.S.N.M. Collection of W. H. Tobias. Cylindrical, drilled beads of wampum were cut from the shell of the hard-shell clam (*Venus mercenaria*) which gave beads of purple and white colors. Woven belts of wampum served as objects of personal adornment, and had a certain ceremonial value. In western America wampum was replaced by dentalium shell in beaded sashes, belts, and other objects of personal adornment, as earrings and necklaces.

### PLATE 3

Beaded shoulder bags of the Chippewa and the eastern Canadian Indians.

Left: Cat. No. 154030, U.S.N.M. From the Hazen collection. Dimensions: 9 inches deep and 9 inches wide.

Right: Cat. No. 328762, U.S.N.M. Collected by B. R. Ross from the Chippewa Indians. Dimensions: 7 inches deep and 7 inches wide.

The panels of woven beadwork are backed with red flannel strouding. Suspension is by means of a strip of tanned doeskin. In the older examples tanned skins were used instead of flannel strouding, and dyed porcupine quills instead of trade beads of colored glass.

PLATE 4

Headband (lower left) and sashes and belts of woven beadwork. Chippewa Indians.

PLATE 5

Examples of the incomplete scroll design of the northern woodlands tribes, extending from Labrador to the vicinity of the Great Lakes and the valley of the Mackenzie River, also to northern and eastern Siberia. This design is more popularly referred to as the double-curve motive of Algonkian art.

Top: A babiche woven bag, Cat. No. 2551, U.S.N.M., collected by B. R. Ross from the Dog Rib Dene Indians of the Mackenzie Valley. "Babiche" is made of finely dissected tanned buckskin woven in openwork coiling without foundation. The decorative panel appearing near the lip of the bag has been embroidered with split and dyed porcupine quills; the design is a flattened double volute. The bag is 18 inches wide and 9 inches deep.

Middle: A decorated woven garment characteristic of the dress of the Ainu of northern Japan. Embroidered patterns in flowing double volutes or spirals resembling those of the Gold and other Amur River tribes of northern Siberia apparently link up a decorative design area of northern Asia with northern America.

Bottom: Designs from decorated tanned skin shirts of the Naskapi Indians of Labrador. The patterns are applied through painting while farther west they are embroidered; on the Pacific coast, among the Eskimo, similar designs are incised or engraved on ivory. Upper row from specimens in the United States National Museum; lower row, from Peabody Museum.

PLATE 6

An example of Chippewa wood carving, Cat. No. 17535, U.S.N.M., collected by J. H. Clark. The engraved and flat-relief patterns resemble in part the double-curve motive of eastern Algonkian art, and in part the geometrical, acute triangular designs of the Plains tribes. Art designs generally prevalent among the Chippewa, Menominee, Winnebago, and other western Great Lakes tribes are transitional between floral, curvilinear motives of the eastern woodlands tribes and the geometrical art of the Indian tribes of the Plains.

PLATE 7

Saddlebags or "parfleches" of painted rawhide typical of the Plains Indians.

Left: Parfleche with painted designs typical of the Comanche Indians. Cat. No. 73532, U.S.N.M.

Center: Decorated rawhide quiver of the Comanche, Cat. No. 76689, U.S.N.M. (left), and a decorated rawhide work box of a Comanche Indian squaw, Cat. No. 76421, U.S.N.M. (right).

Right: Painted rawhide parfleche of the Sioux Indians, Cat. No. 17196, U.S.N.M. Plain on reverse; painted in green, yellow, blue, and red colors on obverse in the order indicated. Dimensions: 29 inches long; 17 inches wide.

PLATE 8

Decorated and painted rawhide quivers, woman's workbox, and other containers of painted rawhide from the Sioux, Comanche, Kiowa, Cheyenne, and Apache Indians.

Upper left: Workbag of a Comanche Indian squaw. Cat. No. 6906, U.S.N.M. It is a cylinder of rawhide sewn at the side and provided with suspension thong and lid. Painted geometrical designs in black, blue, red, and yellow colors. Collected by Palmer.

Upper center: Flat rawhide bag of the Cheyenne Indians painted on both sides in red, blue, and yellow colors. Dimensions: 12 inches long; 5½ inches wide. Cat. No. 165910, U.S.N.M.

Upper right: Decorated rawhide quiver of the Sioux. Cat. No. 76836, U.S.N.M. Collected by Gov. R. W. Furnas from the site of the Battle of White Stone Hill. Painted designs appear in red and blue. The quiver is sinew-sewn at the side where a fringed panel has been inserted.

Lower left: Cylindrical quiver of rawhide, painted in geometrical patterns of red, yellow, and blue colors. Danglers of sheet lead form an encircling decorative panel. Fringed at bottom. Collected by E. Granier from the Apache Indians of Arizona. Dimensions: 14 inches deep; 6¼ inches wide. Cat. No. 3808, U.S.N.M.

Center: A work bag of decorated rawhide collected by James Mooney from the Kiowa. A typical example of Kiowa art in yellow and green painted colors. Cat. No. 152966, U.S.N.M.

Lower right: The rawhide workbag of a Sioux Indian squaw. Painted in green, yellow, and red. A piece of old red flannel strouding has been sewn around the edges as a marginal decorative embellishment. Collected by the Washington branch of the Scottish Rite. Dimensions: 9 inches wide, and 6 inches deep. Cat. No. 338845, U.S.N.M.

In shaping rawhide it is folded and sewn while yet plastic; fringed flaps are inserted and sewn to the sides, while the cover flap may either be sewn on or merely a folded section. Triangular painted devices when acute may represent tipis, when obtuse, they may represent mountains or mountain passes, streams, etc., but are devoid of meaning among some of the northern Plains tribes as among the Blackfeet. Rectangles, triangles, spurs, serrations, rake devices, series of dots are given different interpretations by the various tribes who recognize the symbolism of such devices. Thus a series of dots in color may represent a herd of buffalo, a stream, or a trail.

PLATE 9

Cat. No. 343993, U.S.N.M. Painting in colors on tanned buckskin representing Sioux Indians stealing horses from their enemies. Collected by W. W. Anderson.

Pictographic art of the Sioux is similar in character to paintings of hunting and travel scenes on rock cliffs in the plateau country west of the Rocky Mountains. It is extemporaneous, not symbolic art.

PLATE 10

Beaded and quilled pipe and tobacco bags of the Sioux Indians.

Left: Cat. No. 272207, U.S.N.M. Pipe bag of Red Cloud, chief of the Oglala Teton Sioux. Dimensions: 18 inches long; 8 inches wide. Bequest of Fannie A. Weeks.

Right: Cat. No. 303379, U.S.N.M. Pipe bag of the Sioux Indians. Dimensions: 18 inches long; 8 inches wide. Collected by Wanbli Hoksila.

PLATE 11

Fig. 1. Woven bags of the Nez Perce, Okinagan, and Salish Indians.

Upper left: Cat. No. 220447, U.S.N.M. From Fred Harvey collection of Nez Perce objects at the Louisiana Purchase Exposition. Plain border and bottom with overlay of twined grass on which are embroidered conventionalized butterfly designs in colored woolen yarns. 16½ inches long; 13½ wide.

Second from left: Cat. No. 220450, U.S.N.M. From Fred Harvey collection at the Louisiana Purchase Exposition, Nez Perce. Designs in colored woolen yarns chemically dyed and embroidered on twined overlay. Dimensions: 17½ inches long and 14½ inches wide.

Middle row, left: Cat. No. 220448, U.S.N.M. From Fred Harvey collection, Louisiana Purchase Exposition, Nez Perce. Overlay grass design in flat relief, but no embroidered figures in yarn. Dimensions: 15 inches long and 13 inches wide.

Middle row, second from left: Cat. No. 345429, U.S.N.M. From Salish of Washington. Collected by Mrs. G. B. Welch. Designs in embroidered yarn on grass overlay. Dimensions: 11 inches long and 9 inches wide.

Middle row, third from left: Cat. No. 220449, U.S.N.M. From Fred Harvey collection at the Louisiana Purchase Exposition. Plain field; designs in colored yarns. Dimensions: 15½ inches by 12½ inches.

Lower row, left: Nez Perce. Fred Harvey collection at Louisiana Purchase Exposition.

Lower row, second from left: Cat. No. 177610, U.S.N.M. From Okinagan of Washington. Collected by Mr. C. L. Fletcher. Red flannel border reinforcement; designs in colored yarns. Dimensions: 12½ inches long by 11 inches wide.

Lower row, third from left: Cat. No. 277609, U.S.N.M. From Okinagan. Collected by Mrs. C. L. Fletcher. Flannel strouding border; designs in dyed wollen yarns. Dimensions: 12½ inches long by 9½ inches wide.

Fig. 2. Woven bags of the Nez Perce, Okinagan, and Salish Indians.

(Designs on reverse side of bags figured at left.)

Upper row, second from right: Cat. No. 220447, U.S.N.M. From Fred Harvey collection at the Louisiana Purchase Exposition. Rectangular designs in dyed woolen yarns on a field of overlay grass twining. Dimensions: 16½ inches long by 13½ inches wide.

Upper right: Cat. No. 220450, U.S.N.M. From Fred Harvey collection at the Louisiana Purchase Exposition, Nez Perce. Designs in colored woolen yarns chemically dyed and twined about the warp fabric. 17½ inches long by 14½ inches wide.

Middle row, third from right: Cat. No. 220448, U.S.N.M. From Fred Harvey collection at the Louisiana Purchase Exposition, Nez Perce. Overlay grass design in flat relief. Dimensions: 15 inches long by 13 inches wide.

Middle row, second from right: Cat. No. 345429, U.S.N.M. Salish. Collected by Mrs. G. B. Welch. Plain field designs in colored yarns of light blue, red, yellow, and black; also in dyed grass twining. Dimensions: 11 inches long by 9 inches wide.

Middle right: Cat. No. 220449, U.S.N.M. From Fred Harvey collection at the Louisiana Purchase Exposition. Designs in colored yarns twined about warp elements, Nez Perce. Dimensions: 15½ inches by 12½ inches.

Lower row, third from right: Nez Perce. Overlay of twined grass in various colors forming triangle and diagonal spur designs in flat relief. This is an older decorative technic than embroidery in colored yarns.

Lower row, second from right: Cat. No. 277610, U.S.N.M. From Okinagan of Washington. Collected by Mrs. C. L. Fletcher. Dimensions: 12½ inches long by 11 inches wide.

Lower right: Cat. No. 277609, U.S.N.M. Okinagan. Collected by Mrs. C. L. Fletcher. Border of red flannel strouding; designs in dyed woolen yarns. Dimensions: 12½ inches long by 9½ inches wide.

PLATES 12 AND 13

Woven pouches of the Nez Perce Indians of Idaho, and of the Menominee from the Hrdlička, Bushnell, Matthews, Wetheral, and Fred Harvey collections.

PLATE 14

Pictographic art from the valley of the Middle Columbia River at Vantage Ferry, Kittitas County, Washington. The etched figures of a man and of a mountain goat (A) are perhaps the most characteristic forms of petroglyphs to be seen on the basalt cliffs of the Middle Columbia. Other types of carving of the human figure may be seen (D) at bottom of plate. The elaborate headdress is often confused with figures representing the sun disk. Rain symbols in the form of rake figures also appear in this pictograph. A many-legged insect is frequently engraved on rock (C) as are also figures of lizards, big horn, sheep, deer, flying geese, snakes, bear tracks, bird tracks, sheep horns, and turtle, along with geometric devices such as dots, stars, cogged wheel, cross, concentric circles, wavy or zigzag lines, spirals, connected circles, which are sometimes bisected, circular gridirons, cross hachure, angular meander, diamond or lozenge-shaped figures, ladder, and mazes of several descriptions. The dragonlike figure (B) is unique, while life forms as man on horse, dancing figures, or katchinalike representations; that is, wedge-shaped human figurines are not infrequent.

PLATE 15

Decorated dishes of carved wood and spoons cut from the horn of the mountain goat. From the Wishram, Quinault, and other Tribes of the Middle Columbia Valley and representative of the so-called Dalles Culture which is transitional between the north Pacific coast and the Upper Plateau cultures.

PLATE 16

Native houses and totem poles of the Haida Indians, Kasaan National Monument, Prince of Wales Island, southeast Alaska.

Upper: The house fronted with a single totem pole surmounted with the carved representation of an eagle is the only house remaining. It is named "hutnes," meaning eagle house.

Lower: The house at the right of the village of Kasaan and fronted with two totem poles, was recently burned. It was named the "house of big doings" or "ribs." Built by Chief Skaul. Immediately on the right is another "sky" house, and just beyond is a former slave's cabin.

The National Monument of Old Kasaan is under the administration of the Bureau of Forestry.

PLATE 17

Examples of the wood carver's arts of the Haida Indians of southeast Alaska.

Upper left: A tobacco pipe of carved wood. The pipe is carved to represent the eagle totem; a smaller carved figure just beneath represents a beaver, recognizable by the cross hachure representing its bushy tail, applied for convenience sake on the eagle-figure wing. Cat. No. 337354, U.S.N.M. Collected from the Haida by T. S. Forsyth.

Upper right: One of the most recently erected totem poles in the National Monument of Old Kasaan. It was carved for Chief Nastow in 1886. The two bearded and high-hatted carved figures at the top of the pole are watchmen.

Lower figure: A carved and painted wooden chest. This box is typical of carved and decorated wooden chests fashioned by the northwest Pacific coast Indian tribes and used by them as containers of various objects. The chest is made from a cedar slab grooved on the inner face at proper intervals, bent to a rectangular shape, the ends pegged and a bottom and top supplied. It is decorated by surface painting, by shallow intaglio carving, also by relief carving. The designs are of totemic animals wonderfully analyzed into conventional decorative designs representing totemic forms as in the woven Chilkat blankets. Frequently the smaller chests are secured with an ornamental lacing of cedar bark cord. Sometimes bark mats are wrapped around them before the cords are applied. The carved wooden boxes are intended to contain food or valuable belongings of the household.

PLATE 18

Totemic mask of carved wood and cedar bark representing the culture hero of the Haida and Tlingit Indians of southeast Alaska in the form of a raven. The massive beak is operated with strings from within by the impersonator of the raven totem. Collection of the United States National Museum.

PLATE 19

Examples of recent forms of stone sculpturing by the Haida of Queen Charlotte Islands, British Columbia. Carvings in slate after patterns formerly executed in wood.

At upper left is the "bear mother." This has been styled the best example of aboriginal art from the Pacific northwest coast, in the manner in which the primitive artist has succeeded in modeling the intended symbolism through carving and polishing a slab of slate.

At upper right is a miniature carving of a totem pole; below appears engraved on the inner surface of a carved and polished tray of slate certain mythological monsters of totemic import, but not found in natural history books.

PLATE 20

Examples of modern decorative art of the Alaska Eskimo.

Pictographic engravings on walrus tusks of ivory. The hunting and fishing scenes engraved on the flattened surface of one of the ivory tusks appear in silhouette. These are of an earlier date than the work illustrated by the engravings appearing on the surface of the other tusk, which appear in perspective, framing a modern cribbage board, one of the favored commercial objects offered to the trade by the modern Alaska Eskimo.

The environment of the Alaska west coast Eskimo limits their choice of materials suitable for pictographic and decorative art. From the beginning of their occupancy of Alaska, the Eskimo engraved geometric designs on bone, ivory, and to a lesser extent on wood. Carving in the round in a highly realistic manner, although practiced to a more limited degree, was no less successful, reminding one in this respect of the art of the northwest coast of British Columbia and of southeast Alaska. Embroidered designs were applied on skin garments by the southern Eskimo and by the Aleut.

Early designs were more curvilinear than are the more modern spurred and angular engraved patterns. Repeated use of the eye motive of the northwest coast tribes points to an early connection between these coast peoples, which was only recently broken off by the intrusion of the Athapascans. There is furthermore in these early attempts at decorative art a striking similarity to the incomplete double volutes and double curves of the Aainu of northern Japan, and of the Siberian tribes.

PLATE 21

Coiled baskets of the Panamint and Tulare Indians of Inyo and Tulare Counties, Calif.

The upper (Panamint) basketry tray illustrates the so-called lone pine pattern, while the lower (Tulare) basket is decorated with the diamond rattlesnake pattern.

PLATE 22

Decorated coiled baskets of the Pomo Indians, Mendocino County, Calif. Ornamentation effected principally through sewing in of white shell beads, downy tufts of woodpecker feathers, and in weaving patterns in colored (black) basketry splints to form geometrical designs symbolizing various life forms. The Pomo attach a meaning to the ornamental structure. The same may be said for the designs of the Salish tribes of British Columbia and for the symbolic ornamentation on the basketry of the Alaska Tlingit Indians, although the Haida do not attach much importance to their decorative devices on twined basketry. The beautiful examples of Pomo coiled basketry shown are built up on either a single or 3-rod foundation, are sewn with split sedge root and the stems of tiny feathers are caught under the stitches. Colors are obtained through use of several kinds of bird feathers, as the red from the woodpecker, green from the mallard duck, orange from the oriole, yellow from the meadow lark, black from quail. In the shell pendants variety in colors is derived from the tinted abalone and the white clam.

PLATE 23

Basketry jars of the White Mountain Apache of Arizona; gaming tray of the Pomo; and (below) twined baskets of the Pomo decorated with shell beads and feathers of the red woodpecker and other birds.

PLATE 24

Exhibit in the United States National Museum of the decorative arts of the Apache Indians of Arizona and New Mexico.

The typical Apache decorative designs may be noted in the saddle bags of cut hide and tanned skins, formerly the property of the Apache chief, Geronimo; also on the medicine man's dance shirt of painted and otherwise ornamented tanned skin, all highly symbolic and sacred to the Apache

religious practices. The patterned beadwork on leggings and the peculiar cut of the moccasin last which is recurved at the toe end and expanded to a button-shaped knob, as also the several styles of baskets shown, fully illustrate the art and arts of the nomadic Apache.

PLATE 25

Painted altar of tanned doeskin. Pueblo Indians of New Mexico.

This example of southern Plains Indian art was collected from the Pueblo Indians by Gov. W. F. M. Arny in 1877. It resembles in structure and details of design, a painted symbol of Comanche origin. The painted design of a buffalo is spread out on a tanned doeskin. A lozenge-shaped figure represents the head, recurved diverging horns, several comblike, or rakelike figures and painted triangles make up the design. A spurred border in particular resembles the corresponding sacred device of the southern Plains tribes, notably the Comanche. The design is applied with sticks dipped in glue, which is well rubbed into the tanned skin. When it hardens, the design is brought into relief. Cat. No. 11317, U.S.N.M.

PLATE 26

Mexican and Pueblan textile designs. A woven serape and ceremonial kilts.

Above: Designs incorporating the symbolism of the Hopi. This consists of stepped triangles and of pendent parallel lines. This is the so-called rain cloud design and reappears in several patterns due to the need for conformity with the borders of the textile into which the pattern has been woven. A rounded, dome-shaped figure frequently appears instead of the triangular device, which is similar to the triangular pattern used in the symbolism of the Plains tribes. Below: The Saltillo serape is perhaps the finest example of weaving and of woven decorative design known from aboriginal American tribes. The woven blankets of the Salish, of the Chilkat, and of the Navaho are close seconds so far as pertains to design alone, but are inferior in weaving technic. Except for the yoke pattern, in the example shown, there has been woven throughout, a series of small, lozenge-shaped figures. Other examples of Saltillo serapes incorporate series of small, hour-glass figures in continuous panels. The art of weaving serapes on native Mexican looms has all but become extinct and the few known examples of this textile art are valued highly.

PLATE 27

Decorated earthenware bowls of the Pueblo Indians of Zuñi, N. Mex. The painting of decorative or of symbolic designs in colors has been carried out to an extent far superior to weaving or basketry technic within the area occupied by the Pueblo Indians. Paint brushes of split yucca leaves are commonly used in applying the paint. Before painting on the designs the surface of the vessel has been treated with a slip consisting of white, orange, or yellowish clays reduced with water. This priming coat serves as a background for the painted designs to be applied. Colors for the paints are derived from plants as the bee plant (*Peritoma serrulatum*) which produces a brilliant black, or ochres in shades of red and yellow.

Use of paints in conventional designs pertaining to local mythology is more common than is the painting on of life motives in eccentric or in realistic form. The Zuñi potter separates the available wall space into

several divisions. Neck designs consist of volutes or of double curves, also of triangles and of lozenge-shaped figures. These designs are repeated to produce a symmetrical balance. On the body of the vessel are painted such combinations as the representation of a deer and a rosette representing a sunflower. A series of three terraces may be substituted for the deer and sunflower figures. There may also be found an encircling panel of bird figures with interlocking bills.

PLATE 28

Pictographic earthenware forms and painted designs in combination with eccentric life forms, some of which approach the realistic. Pueblo Indians of Zuñi and of the Rio Grande, N. Mex.

PLATE 29

Woven belts of the Tarahumare, Huichol, and Cora Indians of northern Mexico. From the Lumholtz, Palmer, and Nelson collections from Sonora and Chihuahua. The apparently meaningless angular designs are, according to Lumholtz, symbolic to the highest degree.

PLATE 30

Woven bags of the Cora, Huichol, and Tarahumare Indians of Mexico; also one woven by the Menominee of the Great Lakes or eastern woodlands area introduced here for comparison.

Upper row, left: Cat. No. 204711, U.S.N.M. Hough collection from San Luis Potosi, Mexico. Woven bag with native geometrical design. Dimensions: 3½ inches in width; 5½ inches in depth.

Upper row, second from left: Cat. No. 201072, U.S.N.M. Woven bag of the Cora Indians collected by Nelson. Dimensions: 5 inches deep by 4¾ inches wide.

Upper right: Cat. No. 201077, U.S.N.M. Woven bag collected by Nelson from the Cora Indians. Dimensions: length, 7½ inches by 6 inches in width.

Right, second row from bottom: Cat. No. 204710, U.S.N.M. From the Hough collection, San Luis Potosi, Mexico. Woven with cotton base and woolen weft. Excellent handiwork. Dimensions: 9 inches long by 6 inches wide.

Left, second from bottom: Cat. No. 165381, U.S.N.M. Collected by Palmer. Cora. Dimensions: width, 8 inches; depth, 6¾ inches.

Lower left: From the Bushnell collection representing the woven grass bags of the Menominee Indians of the eastern woodlands area introduced here for comparison with more sophisticated Mexican examples. The zoomorphic designs resemble those of ancient Peru. Dimensions: Depth, 5½ inches; width, 8 inches.

Lower right: Cat. No. 165380, U.S.N.M. Woven cotsa bag collected by Doctor Palmer from the Cora, in northern Mexico. Dimensions: 6 inches by 6 inches.

PLATE 31

Woven poncho with painted decorative design of the Piro Indians of the upper Amazon (above), contrasted with a splendid example of Navaho loom work.

PLATE 32

Aboriginal architectural detail from the country of the Maya illustrating the aboriginal American stone arch, also relief embellishments on the stone walls of a Mayan temple at Chichen Itza.

PLATE 33

Ceremonial figurines of the Choco Indians of southeastern Panama.

These figurines carved from a light wood represent devices used by the Choco medicine man or doctor as aids in the curing of disease. The painted designs are characteristic of the aborigines of Darien and appear also on bark cloth.

PLATE 34

Animal and bird effigies modeled from gutta percha collected by Lieuts. Herndon and Gibbon from Amazonian tribes in 1856. Below: a ceremonial figurine of carved wood from the prehistoric Arawak of Santo Domingo.

The zoomorphic figurine with aviform headdress is mounted on the end of a staff much like those of the Tule, Bribri, and other tribes of Panama and Costa Rica, although the style of carving resembles modeled life forms appearing on earthenware vessels from the Great Antilles. Collected by W. H. Gabb in a cave in Santo Domingo. Cat. No. 42664, U.S.N.M.

PLATE 35

On the left is an ancient Peruvian mummy enshrouded in its original covering of decorated woven cloth. On this example of prehistoric Peruvian cloth appear stamped geometric designs in panels, also the conventionalized figure of a fish, as primary decorative motives in color. Collected by W. L. Safford, U.S.N.

On the right is a decorated bark-cloth shirt collected by F. L. Cushing from a Peruvian tribe on the upper Amazon River. Cat. No. 175807, U.S.N.M.

PLATE 36

South American Indian decorative design and weaving technic.

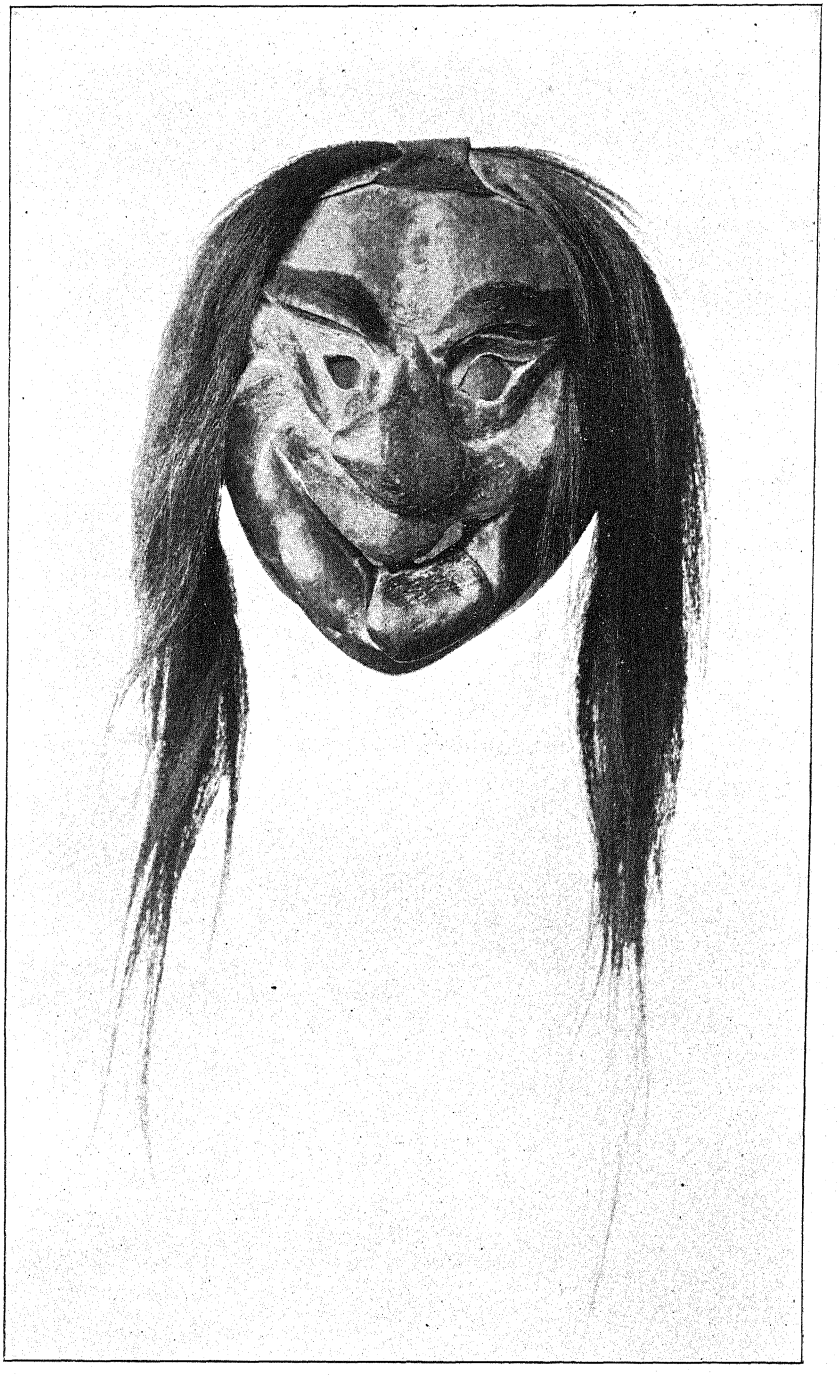
Left: Decorative technic of the Jivaro Indians of Peru in feathers and beads. Above is a loin cloth of woven and plaited feathers of the toucan and other brilliantly-colored birds. Beaded fringes capped with green metallic elytra of beetles are attached to the lower border. Beaded belts and sashes appear at the sides, while at center is an open mesh beaded skirt. Collected by W. L. Safford, U.S.N.

Center: The dark colored skirt, with its ornamental appliqué embellishment of shell beads and danglers, has been woven by the Peruvian Indians from human hair. Collected by W. L. Safford, U.S.N.

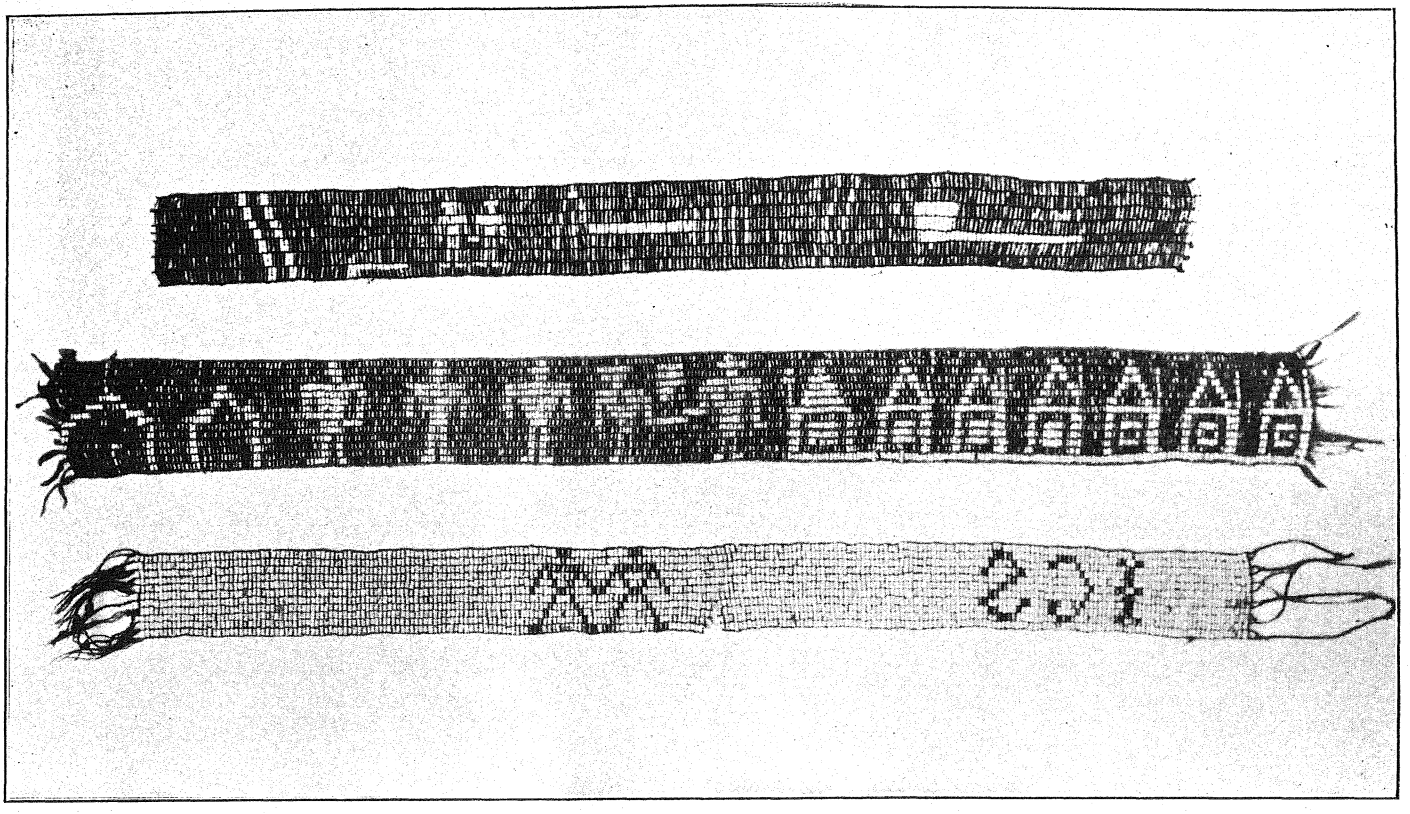
Right: Decorative motives of the Tehuelche Indians of Patagonia. The painted decorative designs are applied on the inner surface of a tanned cow hide to which the hair is still attached. Collected by W. L. Safford, U.S.N.

PLATE 37

War shirt decorated with feathers of the emu. Indians of Paraguay. Similar war jackets of woven cord are in the museum collections from Kingsmill Island and from Negrito tribes of the interior of New Guinea.



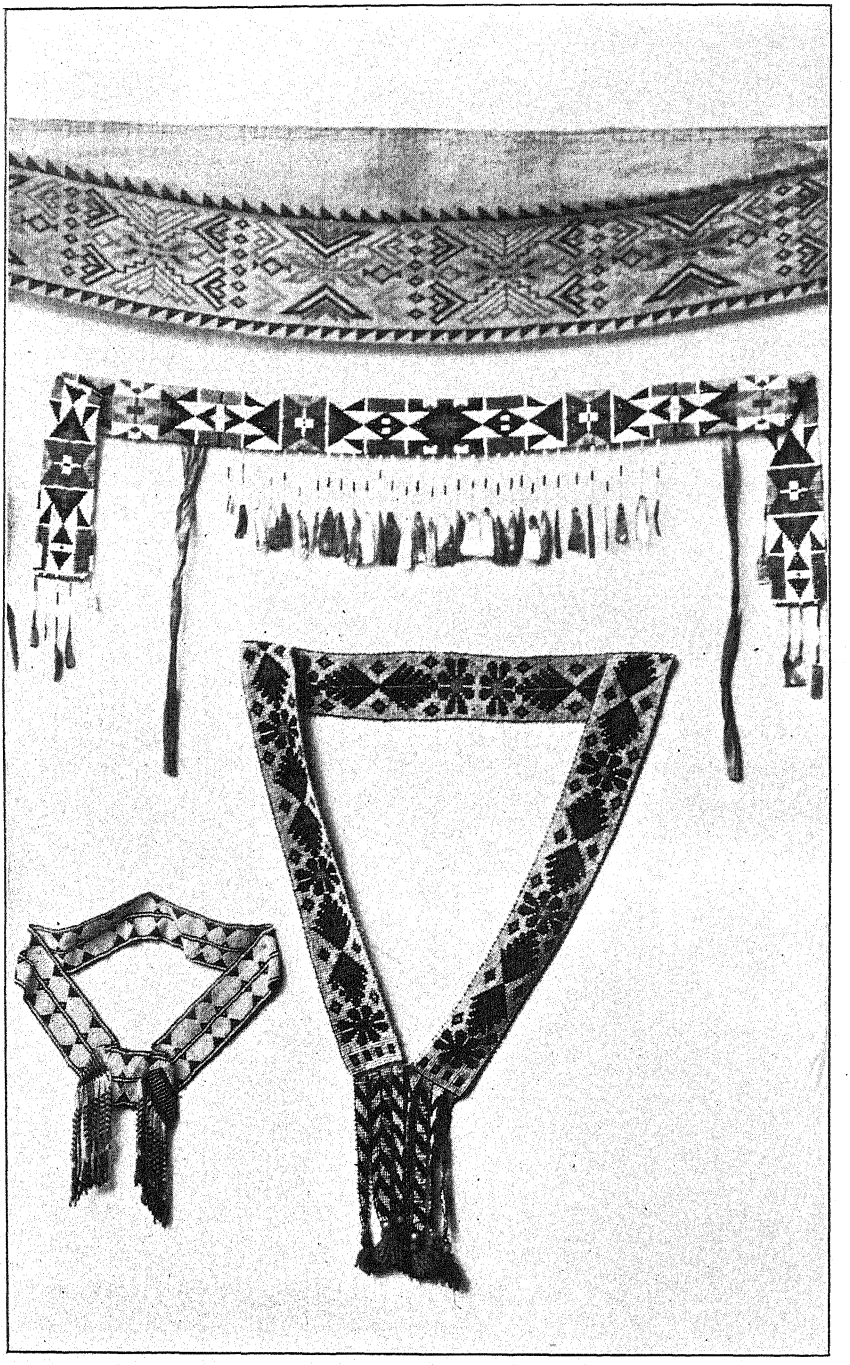
IROQUOIS MASK



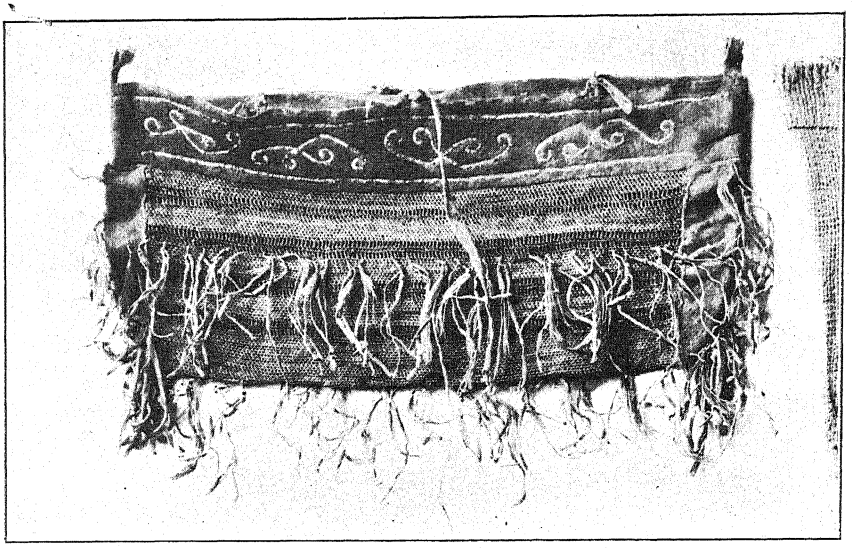
WAMPUM BELTS OF THE IROQUOIS INDIANS

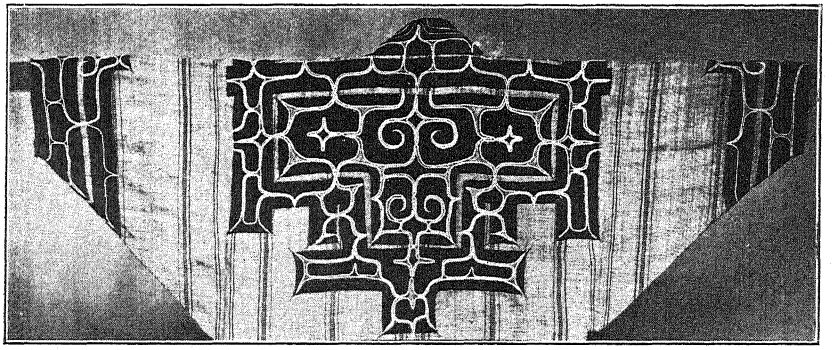


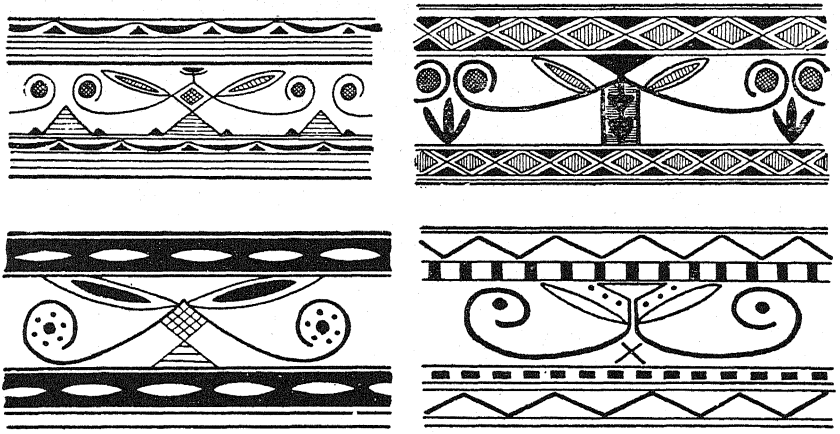
BEADED SHOULDER BAGS OF THE CHIPPEWA INDIANS



HEADBAND (LOWER LEFT) AND SASHES AND BELTS OF WOVEN BEADWORK OF THE CHIPPEWA INDIANS

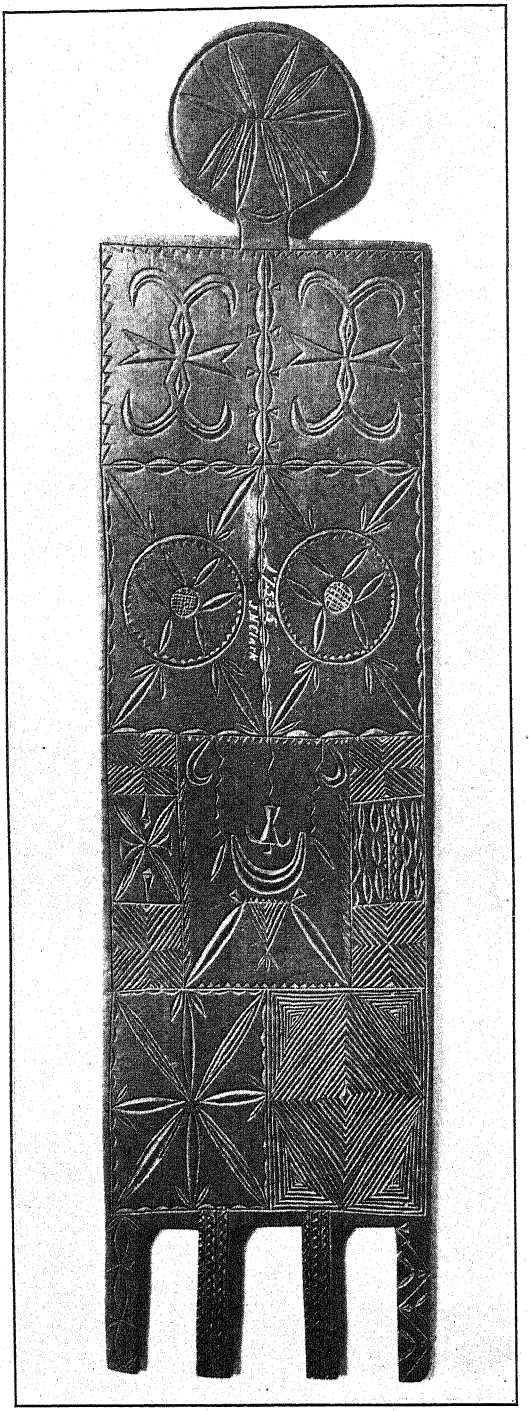




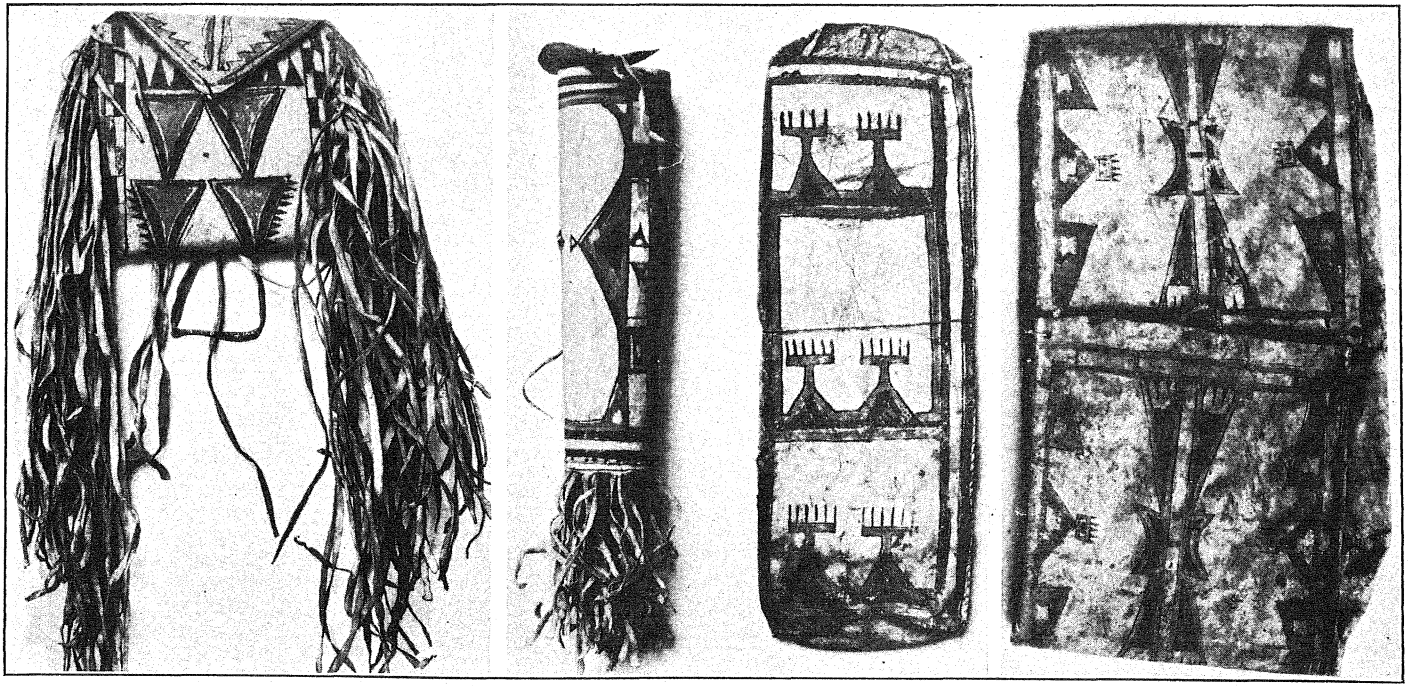


EXAMPLES OF THE DOUBLE-CURVE DESIGN

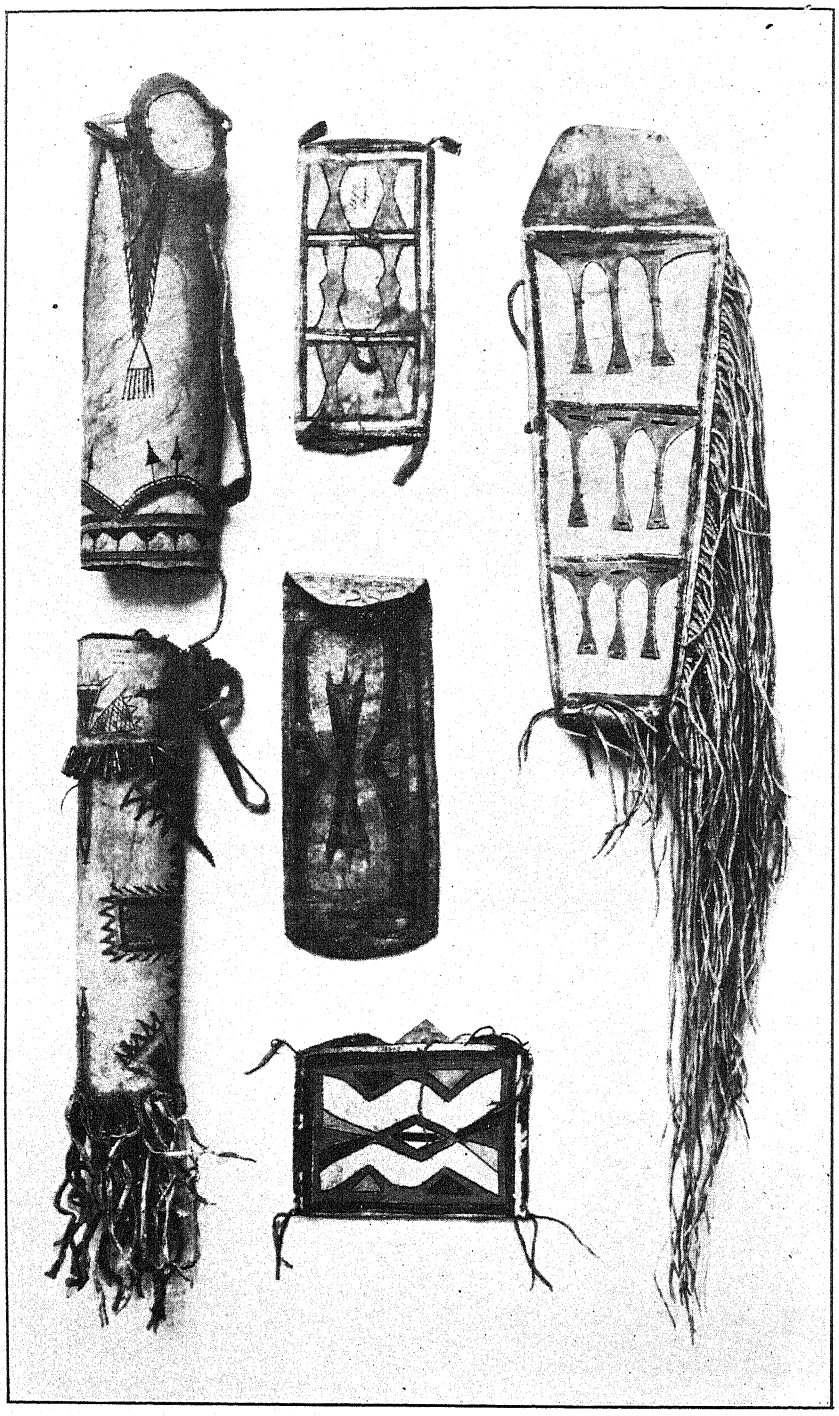
Upper, Dene; Middle, Ainu; Lower, Haida.



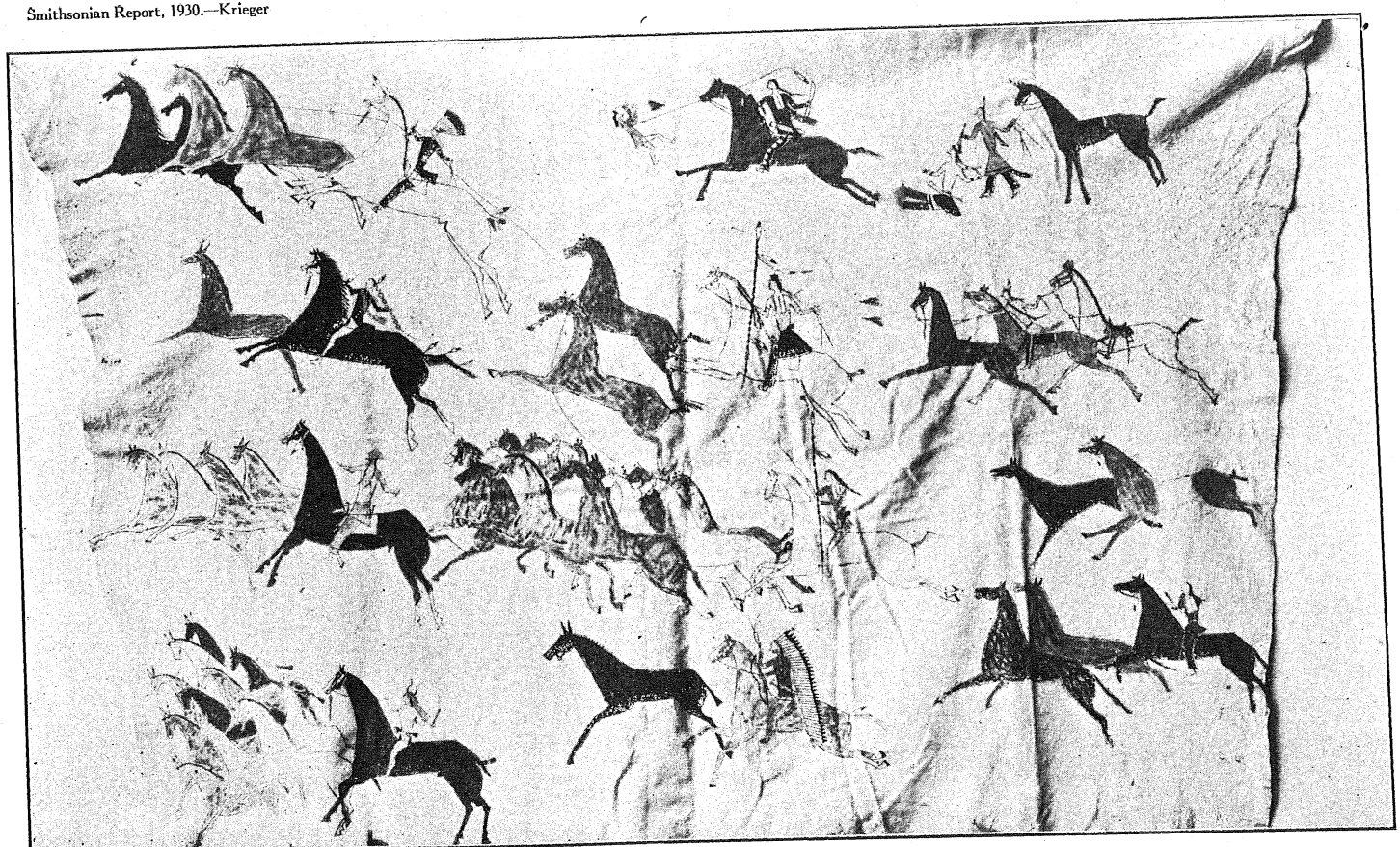
DECORATIVE ART OF THE CHIPPEWA. FLORAL AND GEOMETRIC ENGRAVED DESIGNS ON WOOD



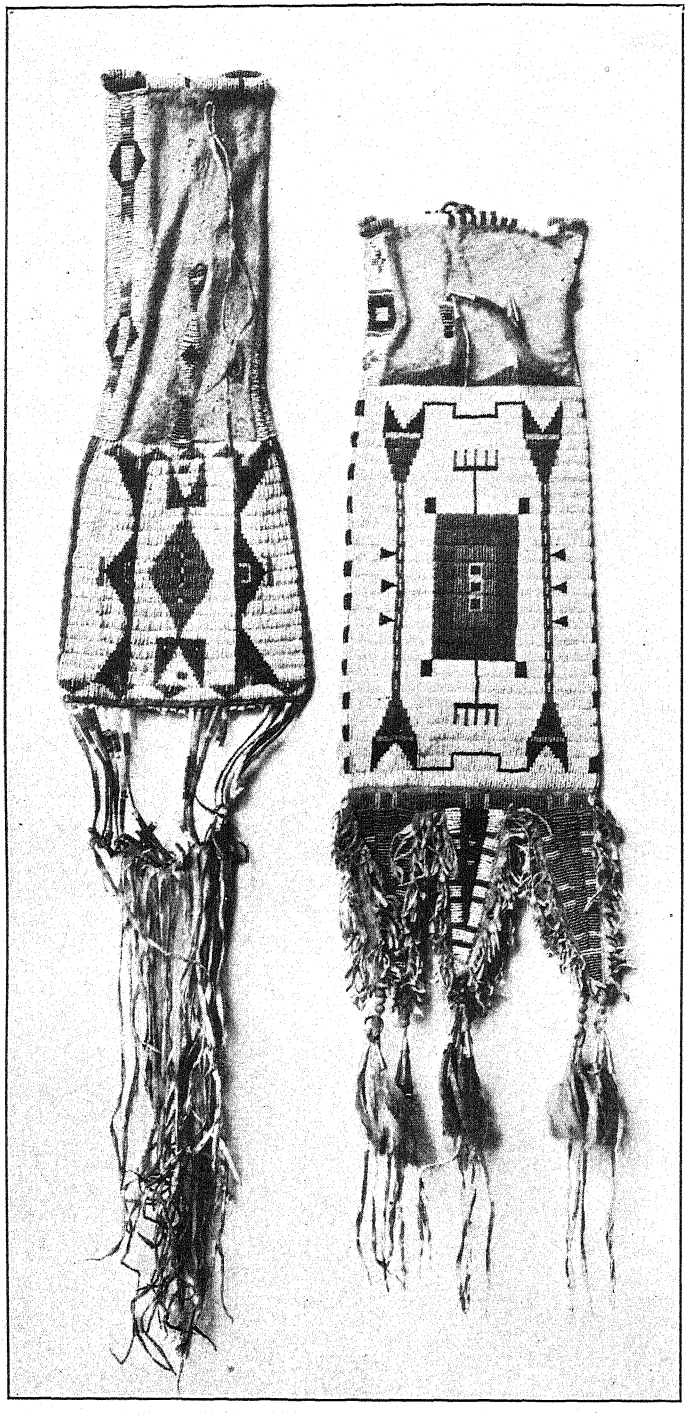
PAINTED RAWHIDE BAGS, QUIVER, AND PARFLECHES OF THE COMANCHE (SIOUX, RIGHT) INDIANS



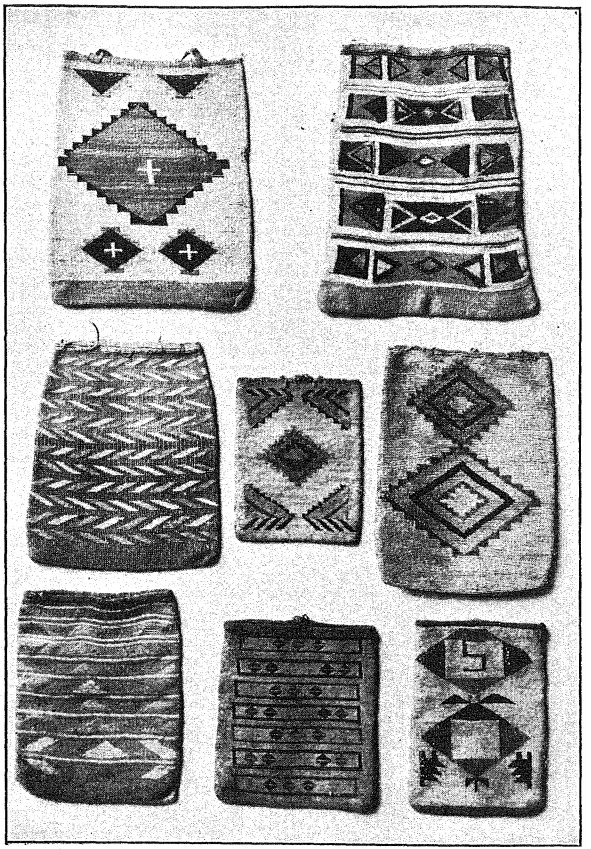
DECORATED QUIVER, WOMAN'S WORKBOX, AND OTHER CONTAINERS OF PAINTED RAWHIDE. SIOUX, COMANCHE, KIOWA, CHEYENNE, AND APACHE INDIANS

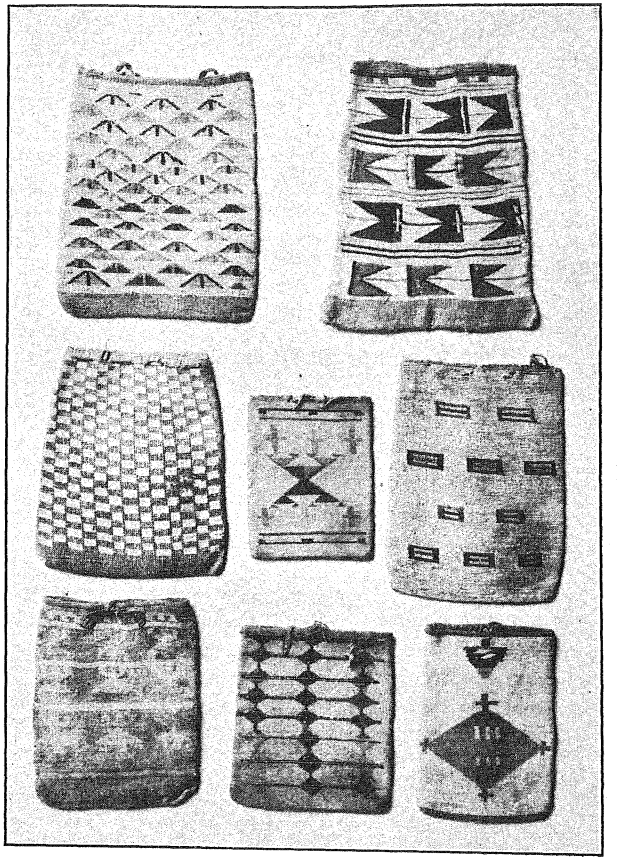


PAINTING ON TANNED BUCKSKIN REPRESENTING SIOUX INDIANS STEALING HORSES

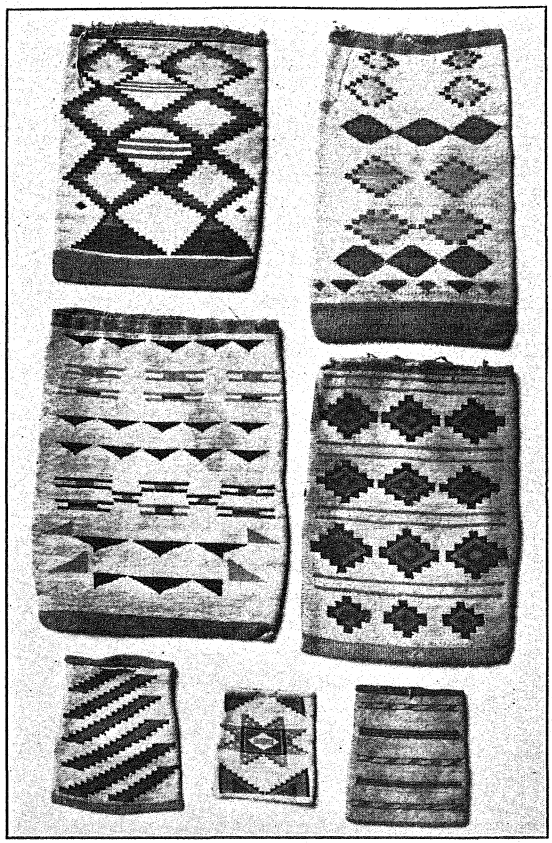


BEADED AND QUILLED PIPE AND TOBACCO BAGS OF THE SIOUX INDIANS



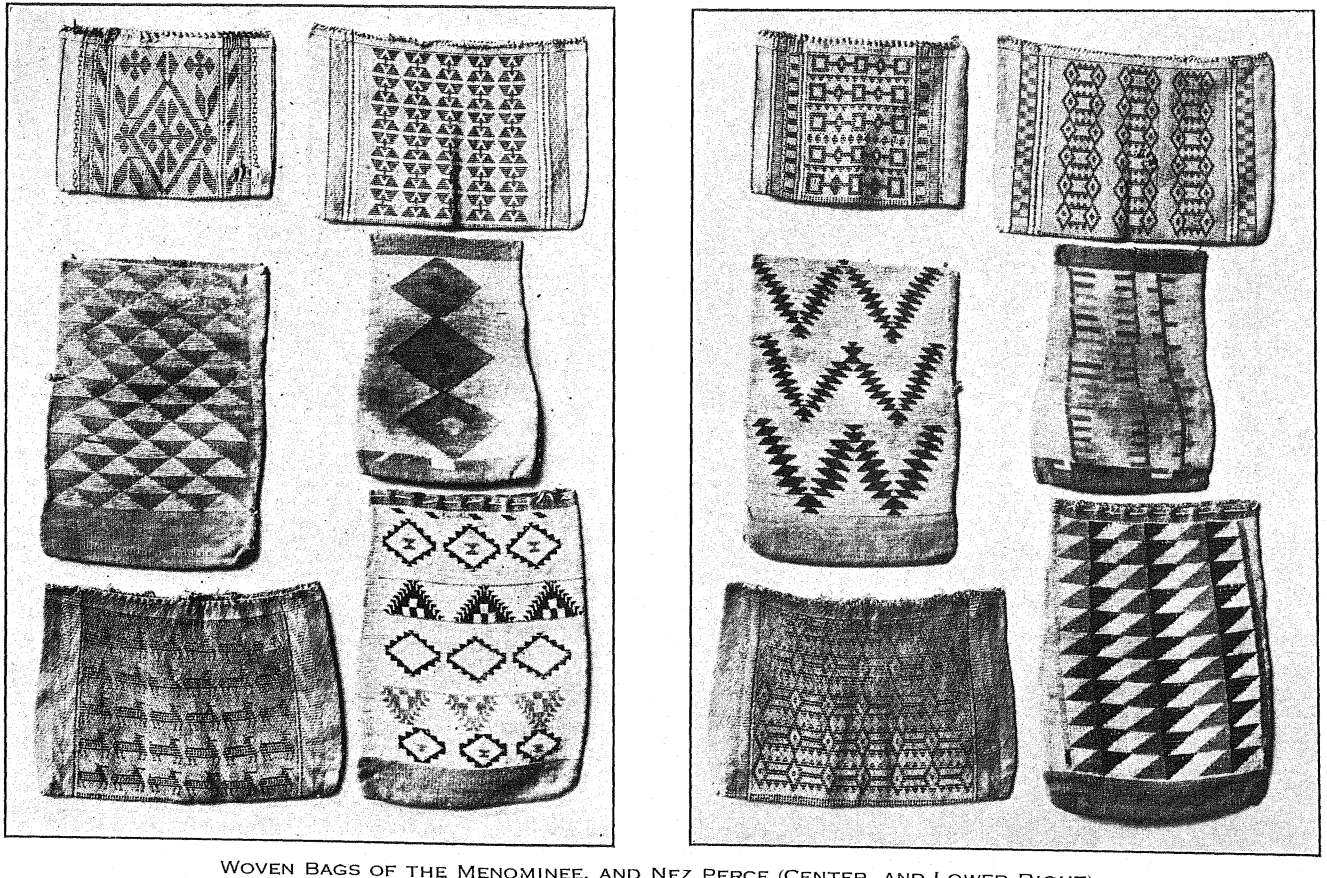


WOVEN BAGS OF THE NEZ PERCE, OKINAGAN, AND SALISH, INDIANS

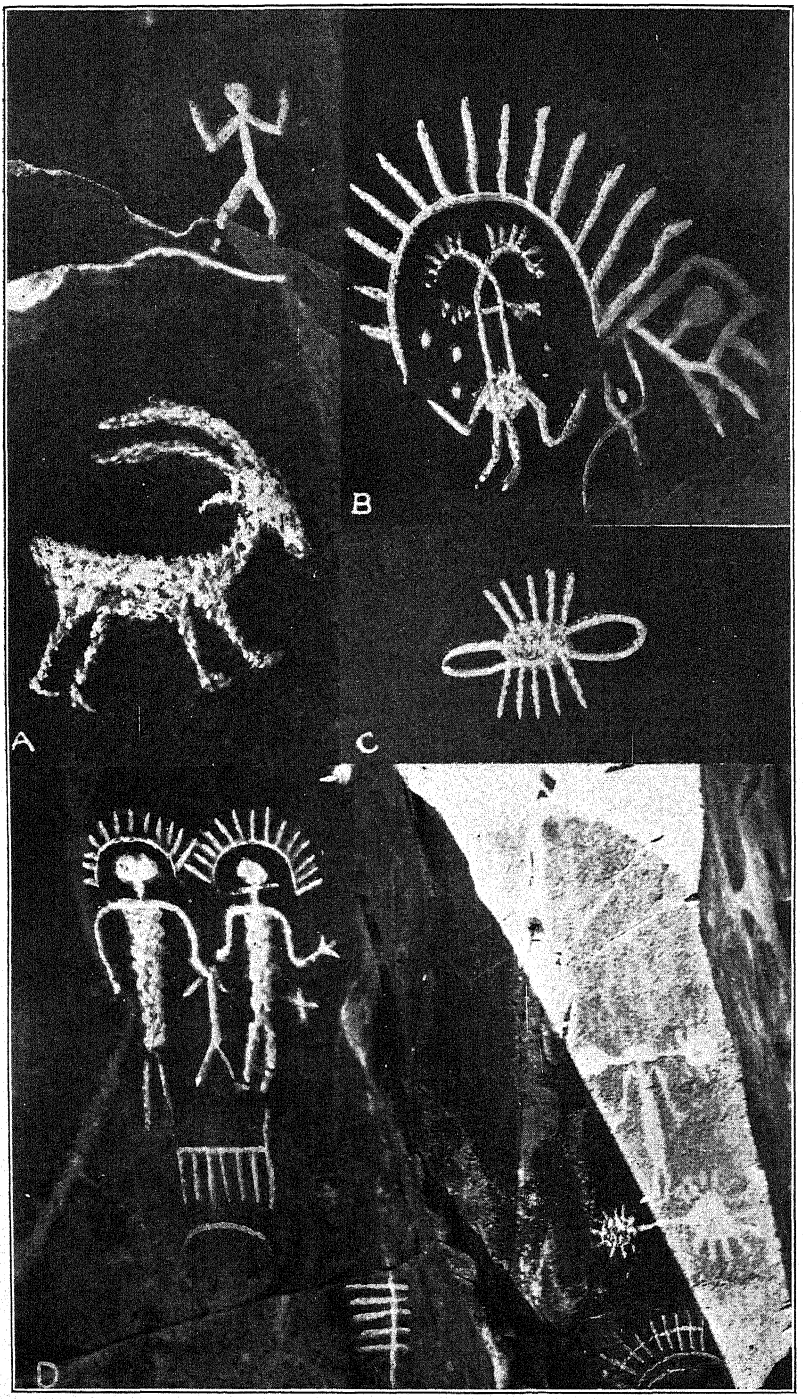




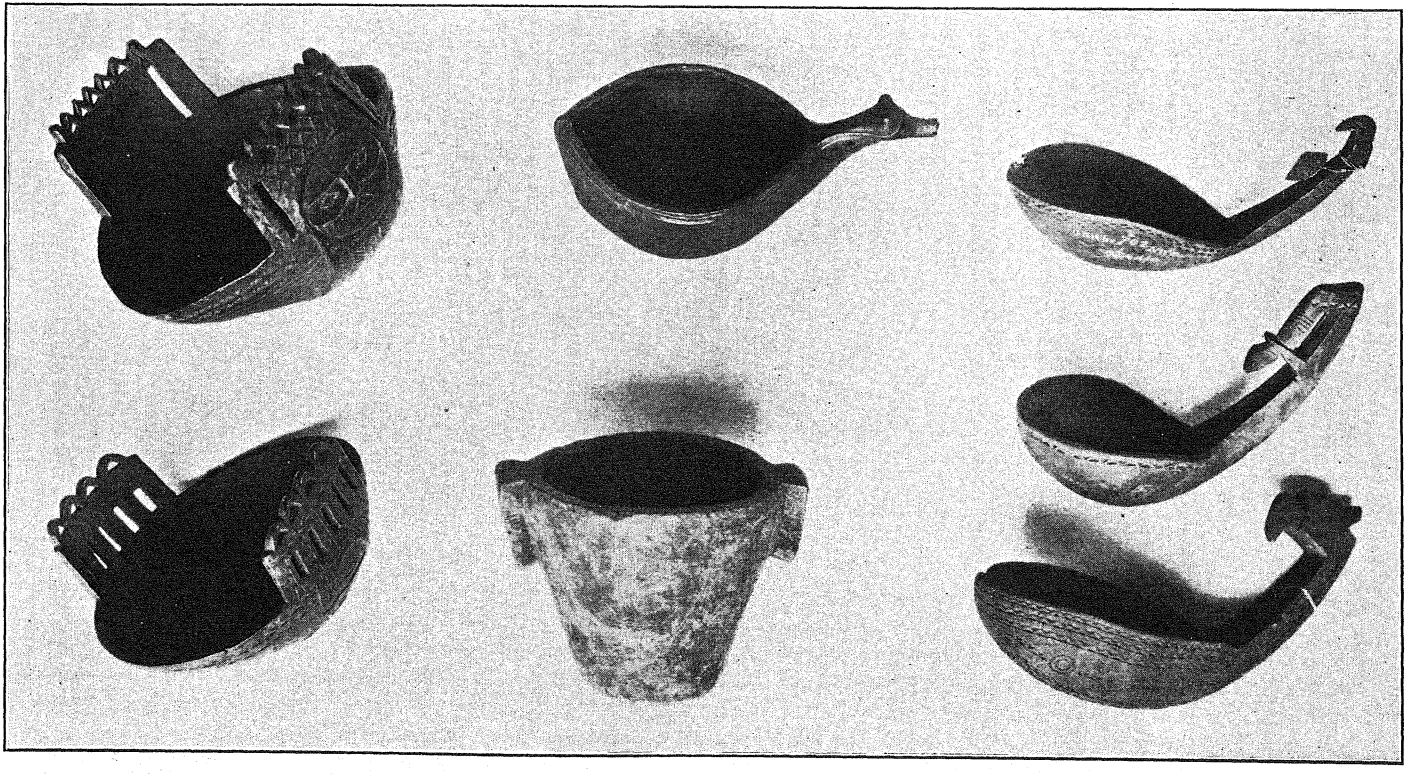
WOVEN BAGS OF THE NEZ PERCE INDIANS OF IDAHO



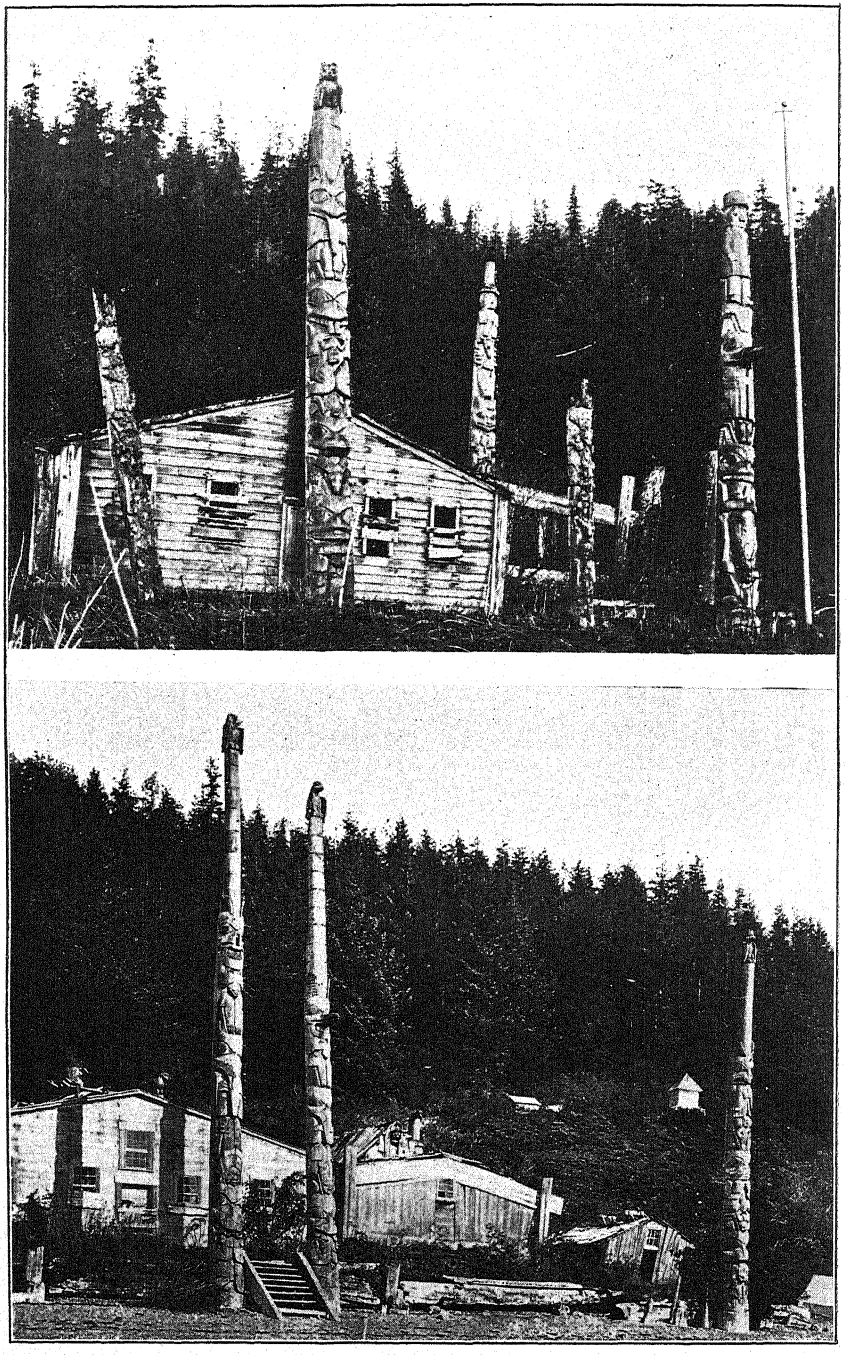
WOVEN BAGS OF THE MENOMINEE, AND NEZ PERCE (CENTER, AND LOWER RIGHT)



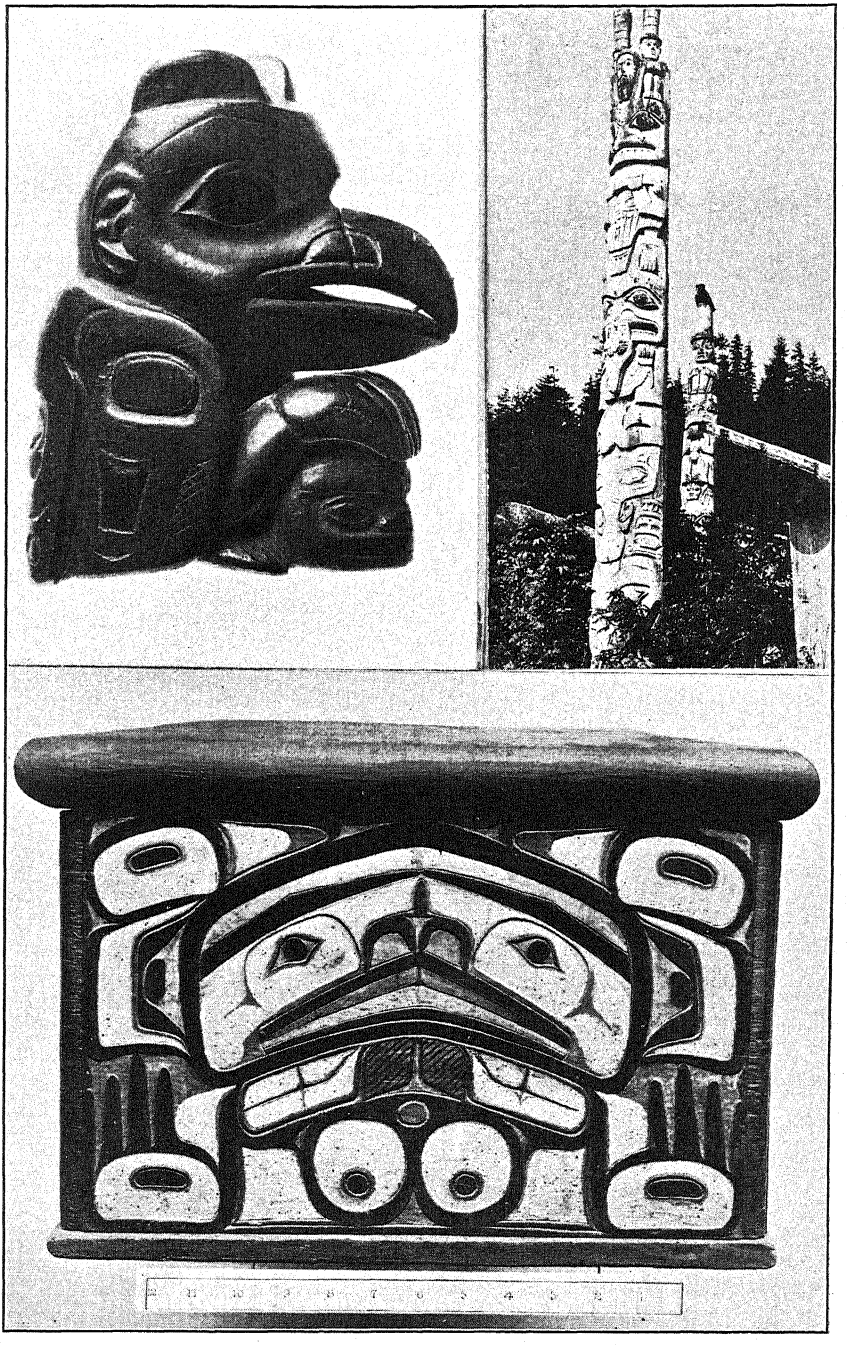

PICTOGRAPHIC ART FROM THE VALLEY OF THE MIDDLE COLUMBIA RIVER AT VANTAGE FERRY, WASH.



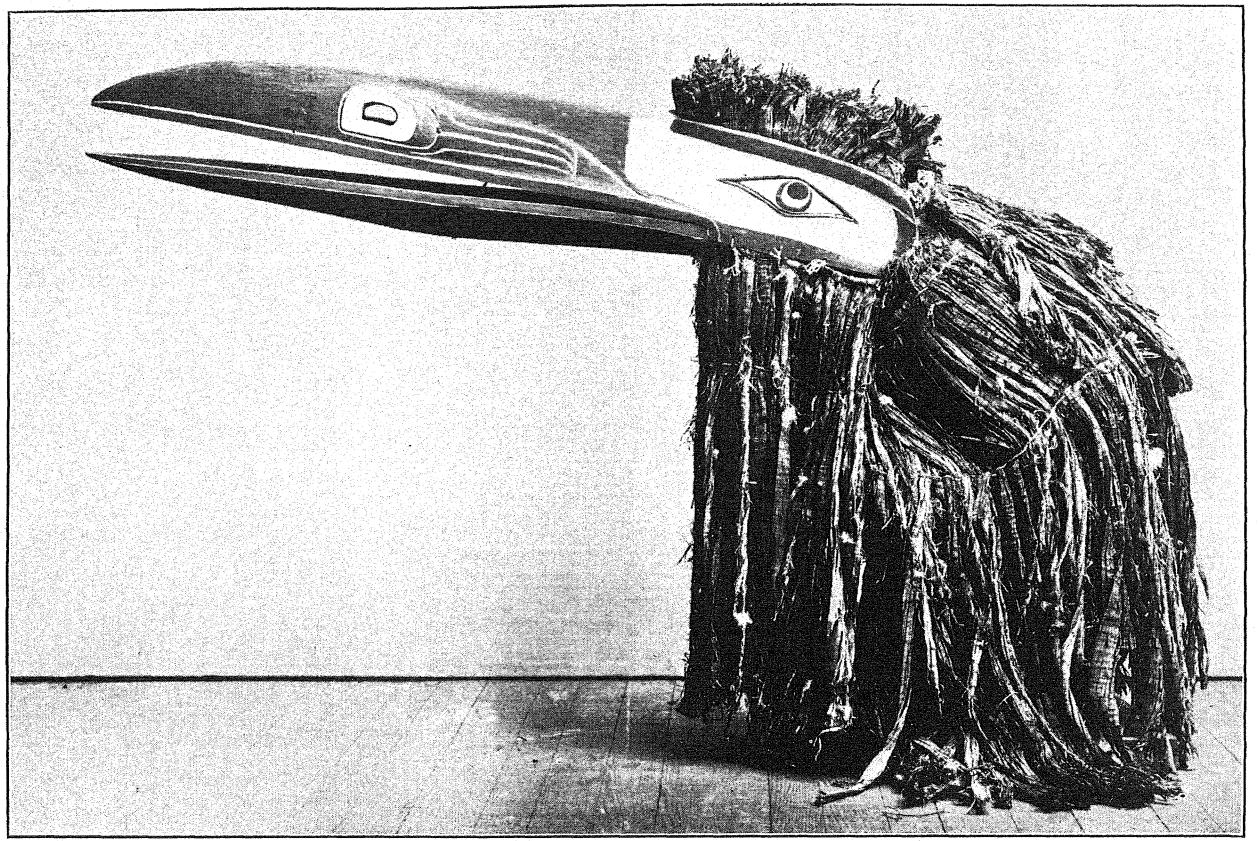
DECORATED DISHES OF CARVED WOOD AND SPOONS CUT FROM THE HORN OF THE MOUNTAIN GOAT. FROM THE QUINAULT, WISHRAM, AND OTHER TRIBES OF THE MIDDLE COLUMBIA VALLEY



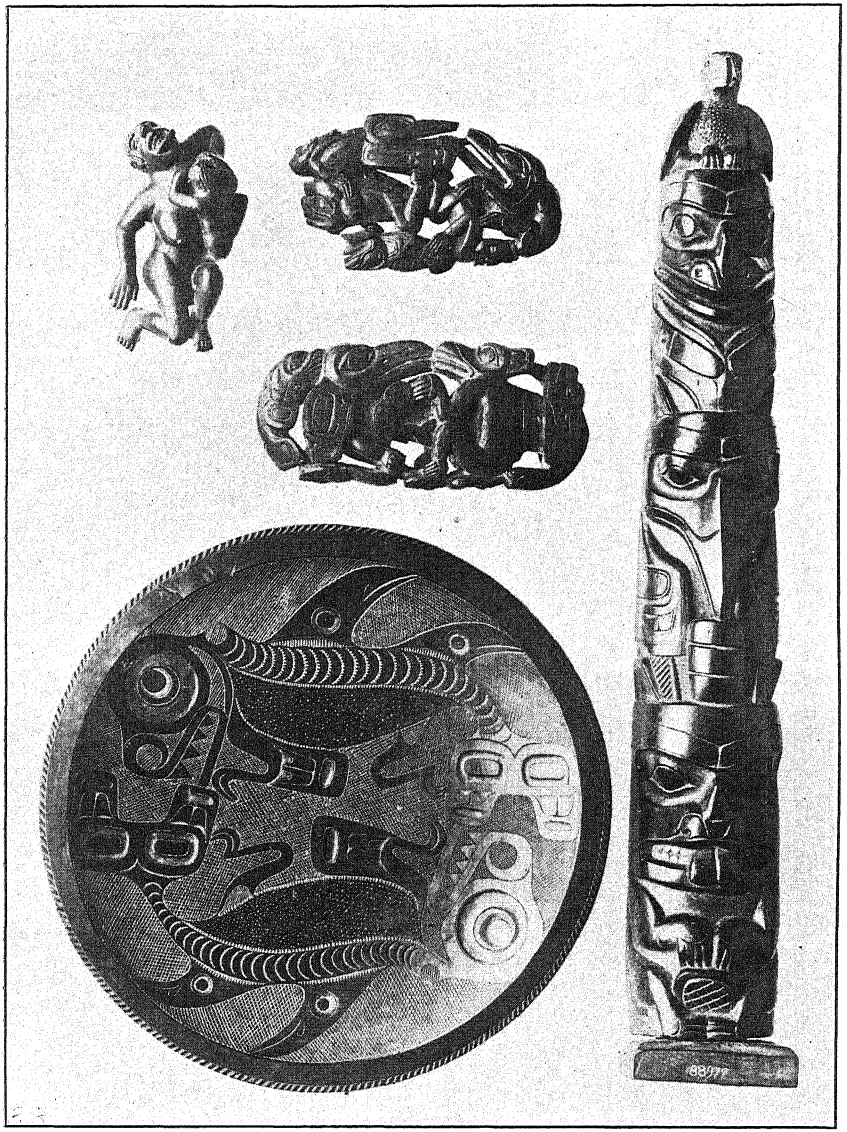
NATIVE HOUSES AND TOTEM POLES OF THE HAIDA INDIANS AT KASAAN, PRINCE OF WALES ISLAND, SOUTHEAST ALASKA



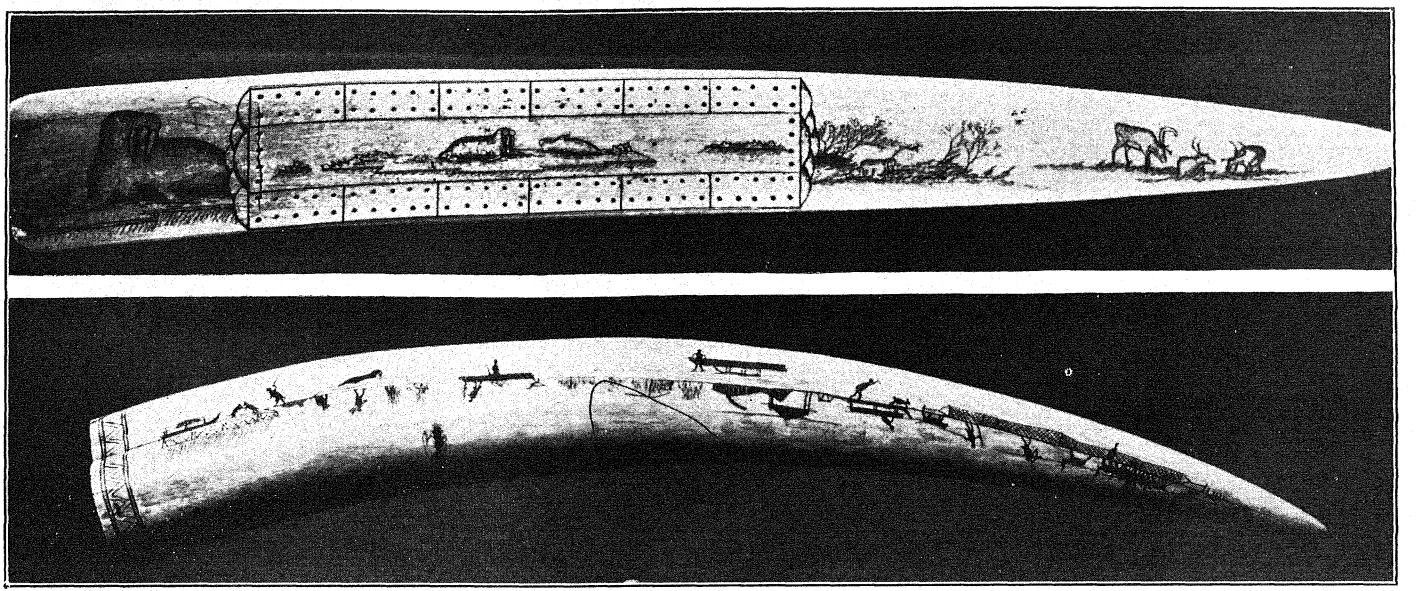
UPPER LEFT, A CARVED WOODEN PIPE; UPPER RIGHT, A HAIDA TOTEM POLE; BOTTOM, CARVED AND PAINTED WOODEN CHEST



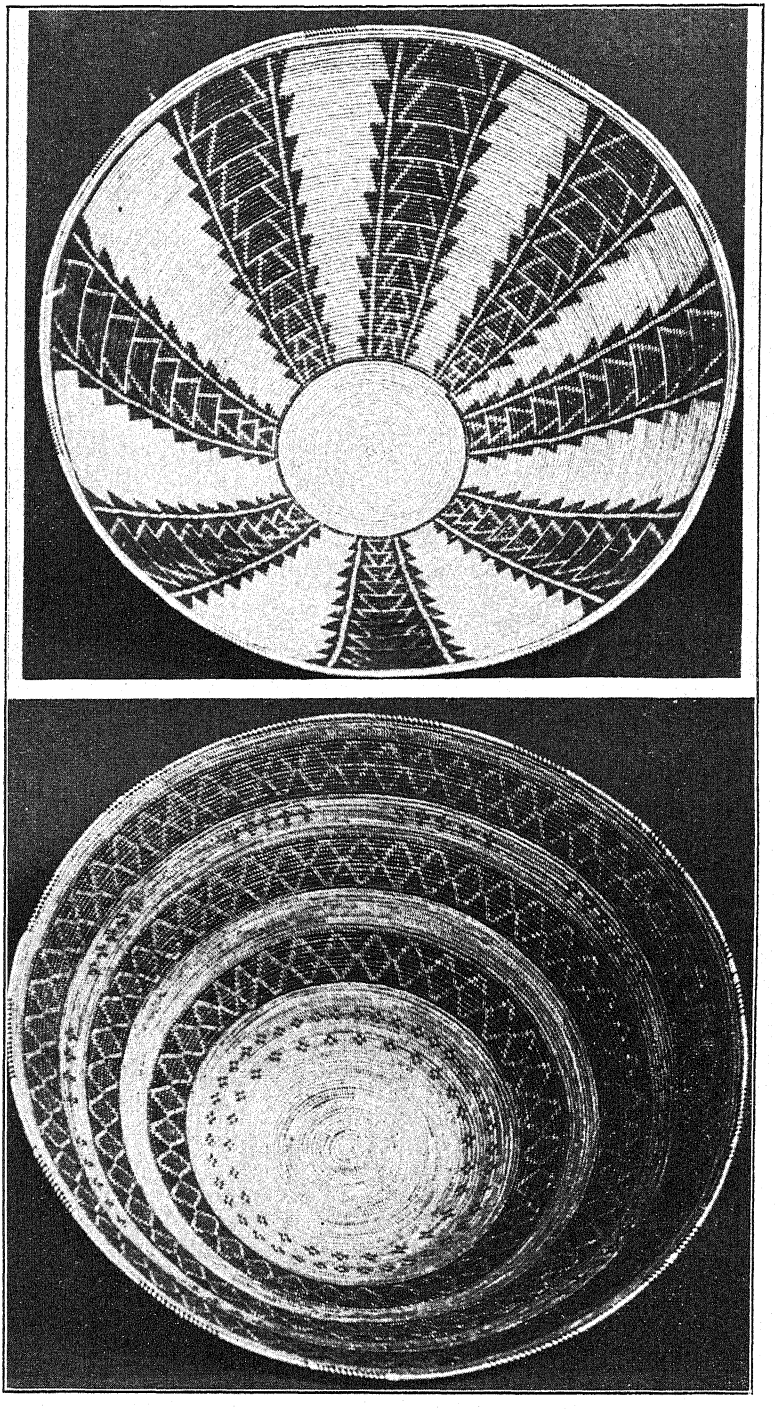
TOTEMIC MASK OF CARVED WOOD AND CEDAR BARK REPRESENTING THE RAVEN. HAIDA INDIANS OF SOUTHEAST ALASKA



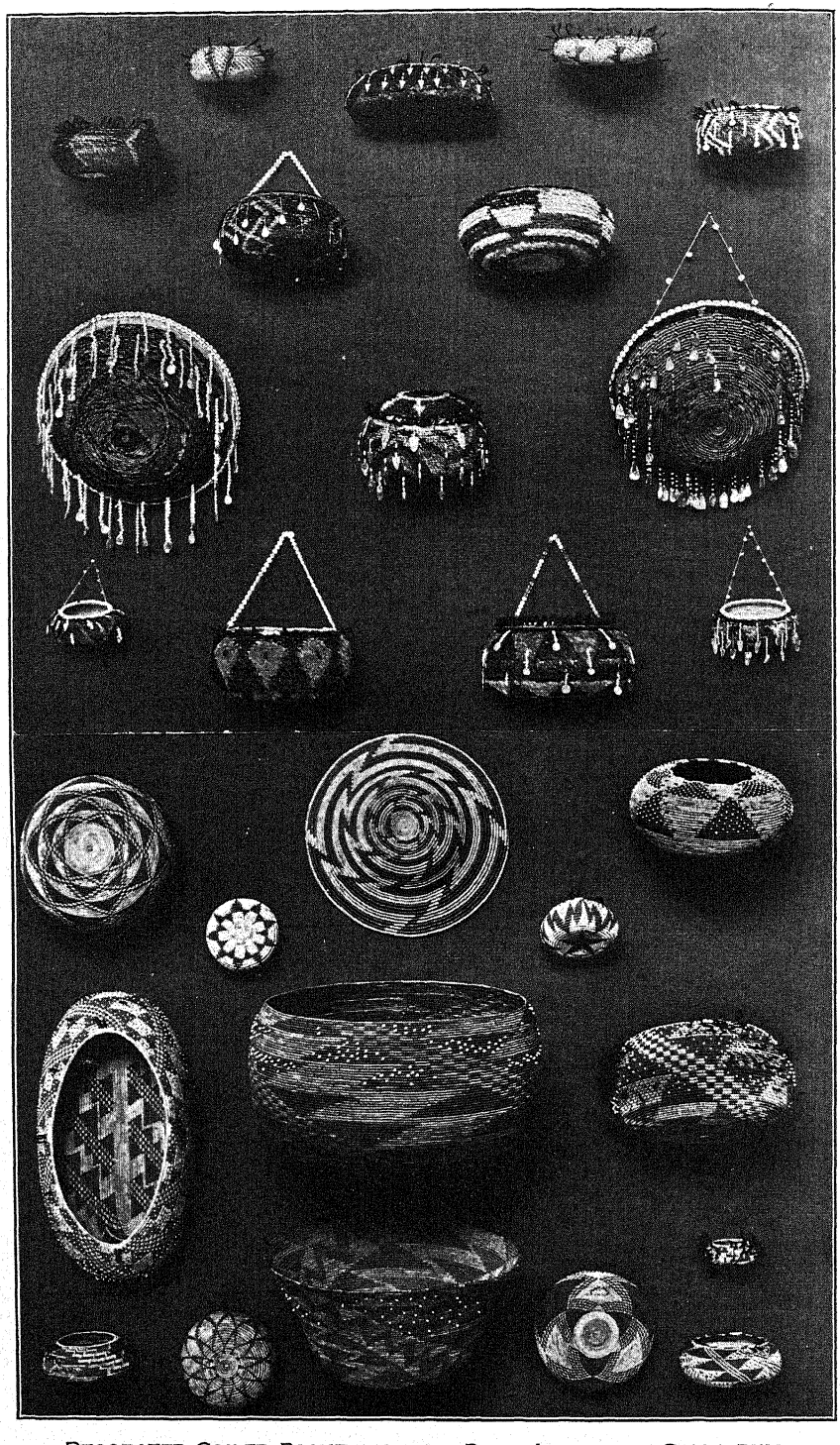
CARVINGS IN SLATE AFTER PATTERNS FORMERLY EXECUTED IN WOOD. HAIDA INDIANS OF QUEEN CHARLOTTE ISLANDS, BRITISH COLUMBIA



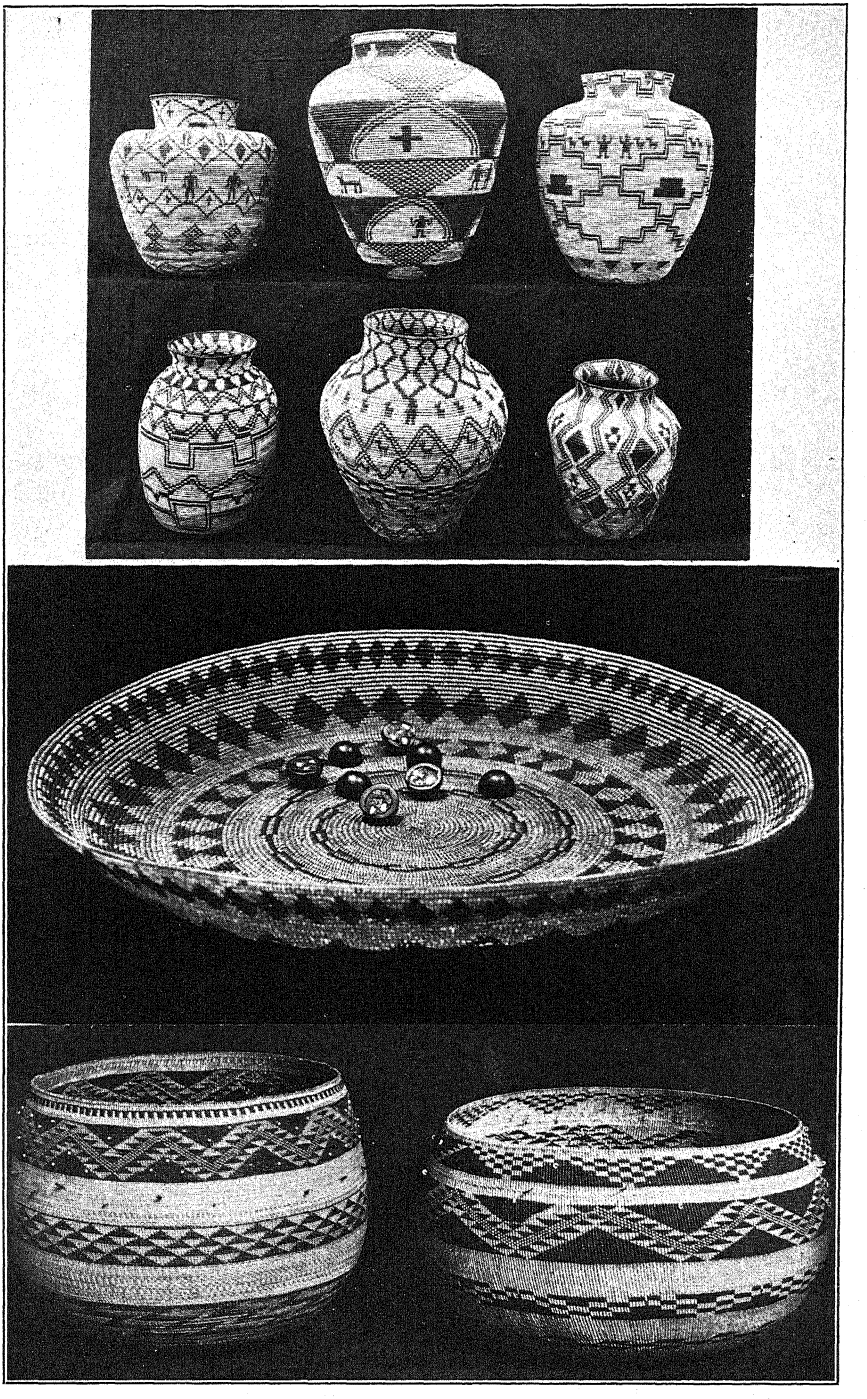
PICTOGRAPHIC ENGRAVINGS ON WALRUS TUSKS BY THE ESKIMO OF ALASKA



COILED BASKETS OF THE PANAMINT AND TULARE INDIANS OF CALIFORNIA



DECORATED COILED BASKETS OF THE POMO INDIANS OF CALIFORNIA



BASKETRY OF THE APACHE AND POMO INDIANS

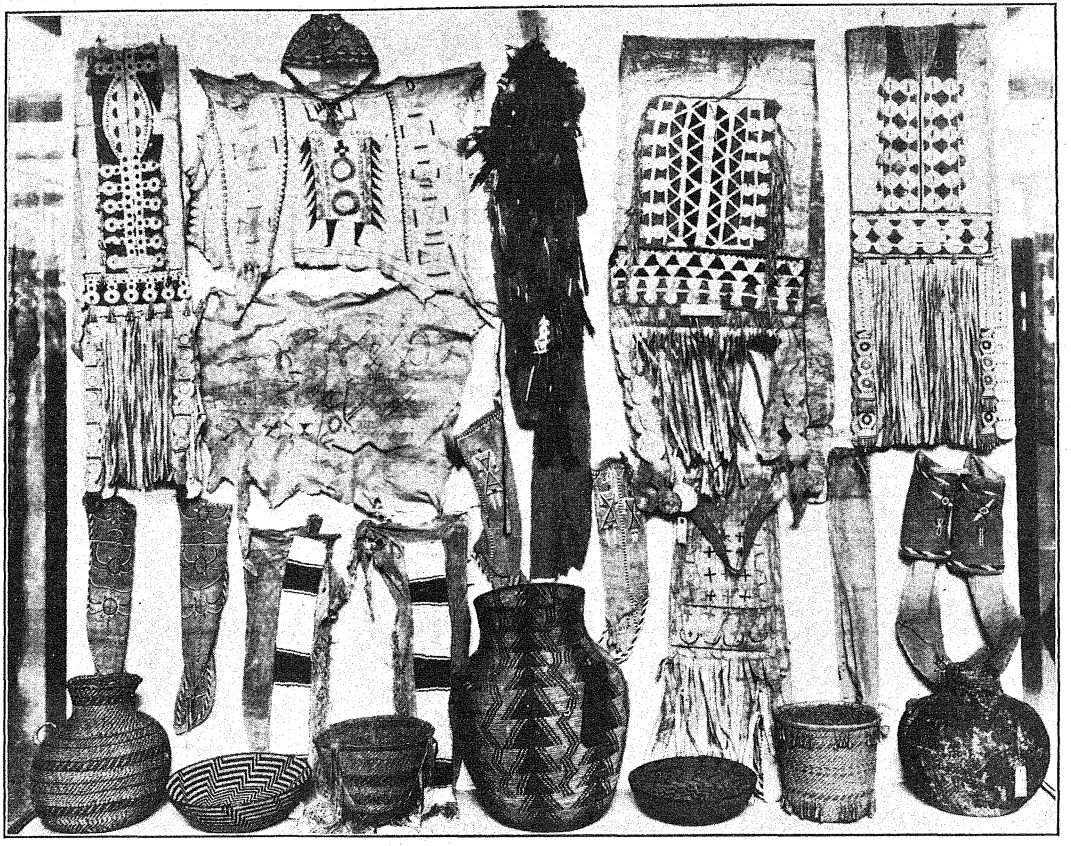
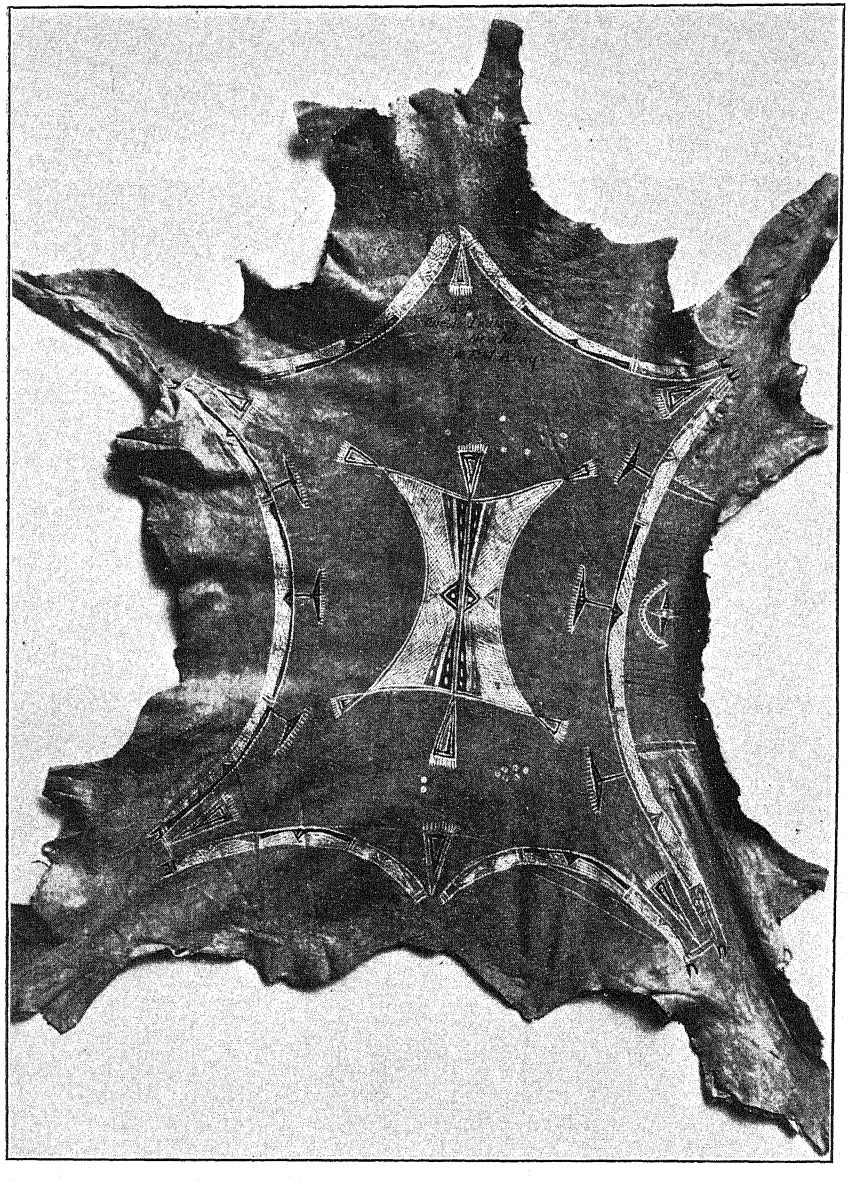
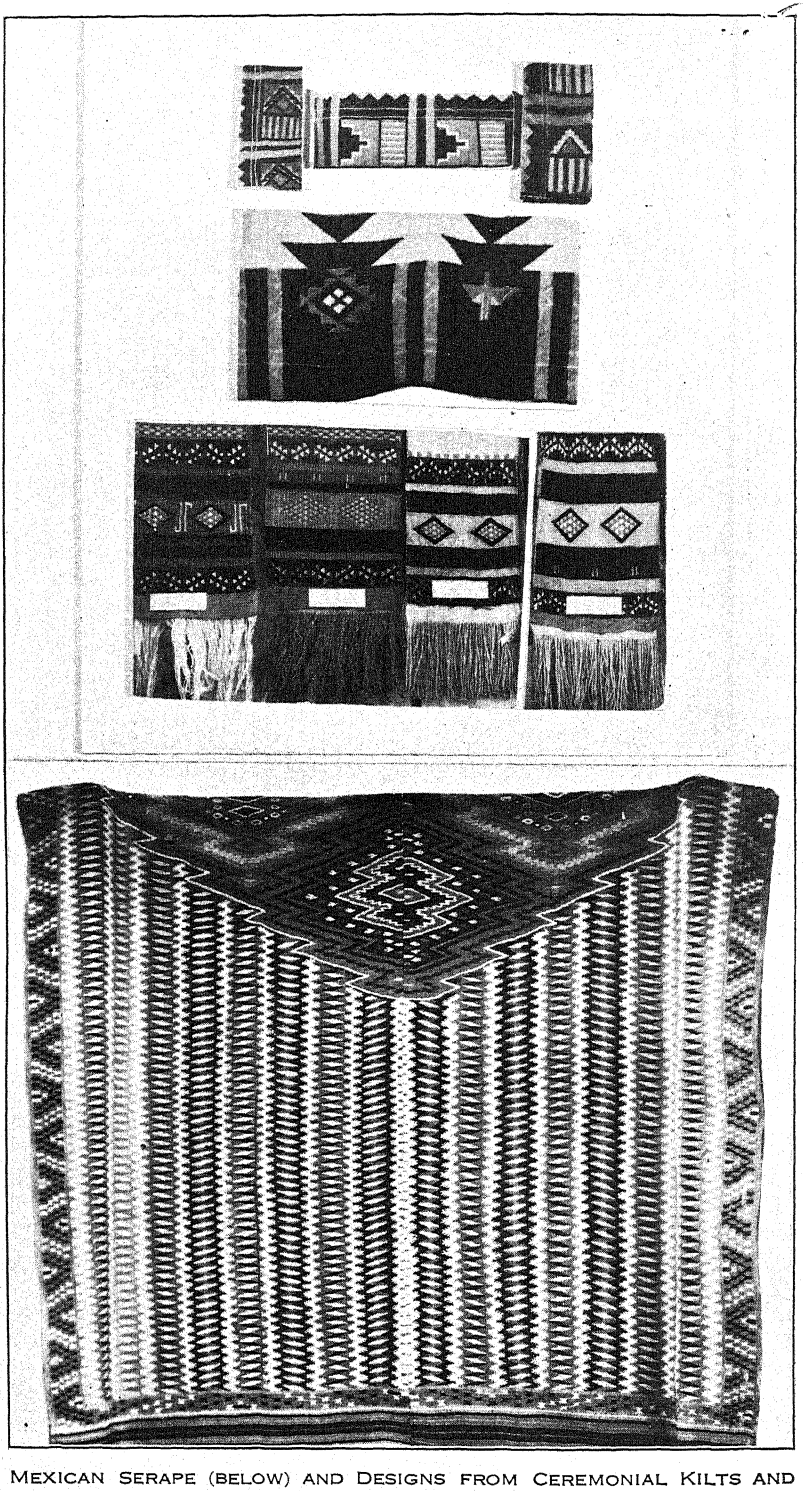


EXHIBIT OF THE DECORATIVE ARTS OF THE APACHE INDIANS



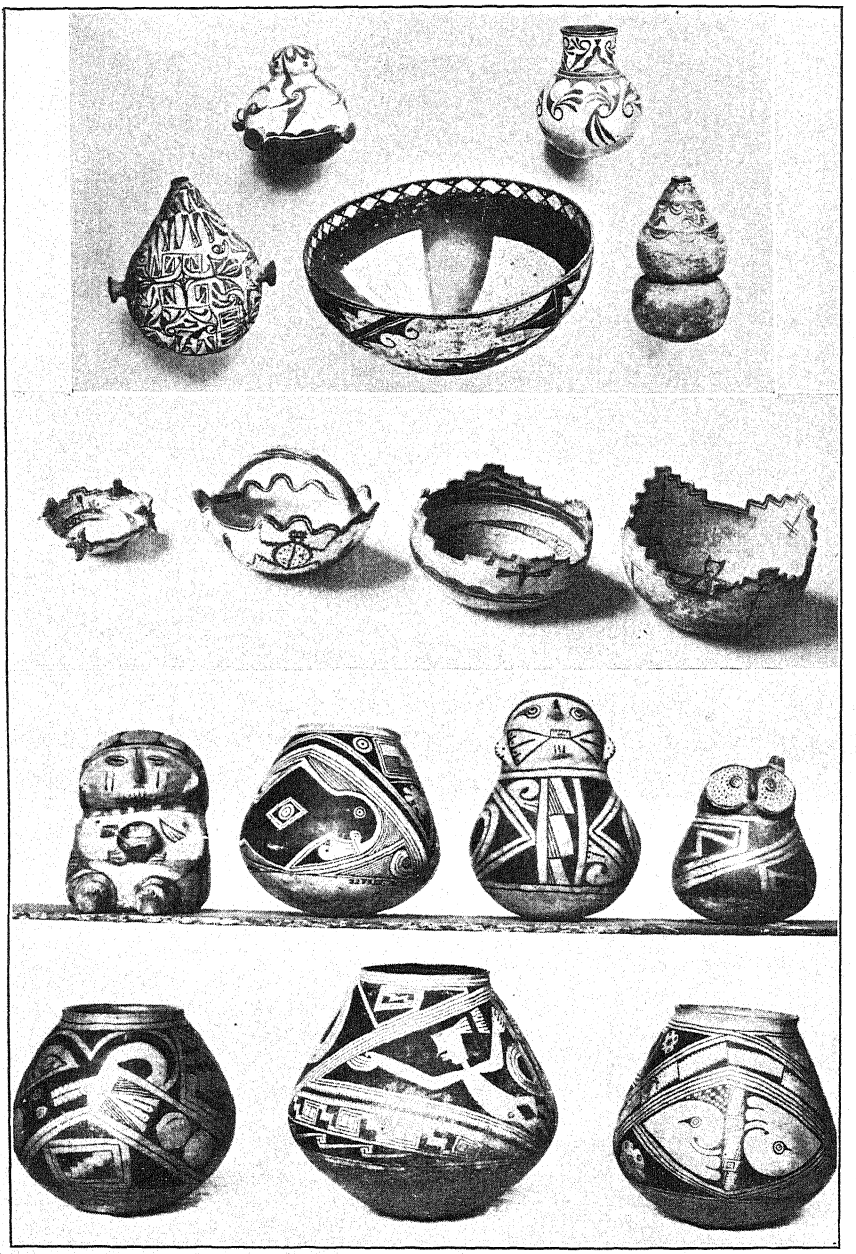
PAINTED ALTAR OF TANNED DOESKIN, SYMBOLIZING THE INDIAN'S PRAYER FOR MORE BUFFALO. PUEBLO INDIANS OF NEW MEXICO



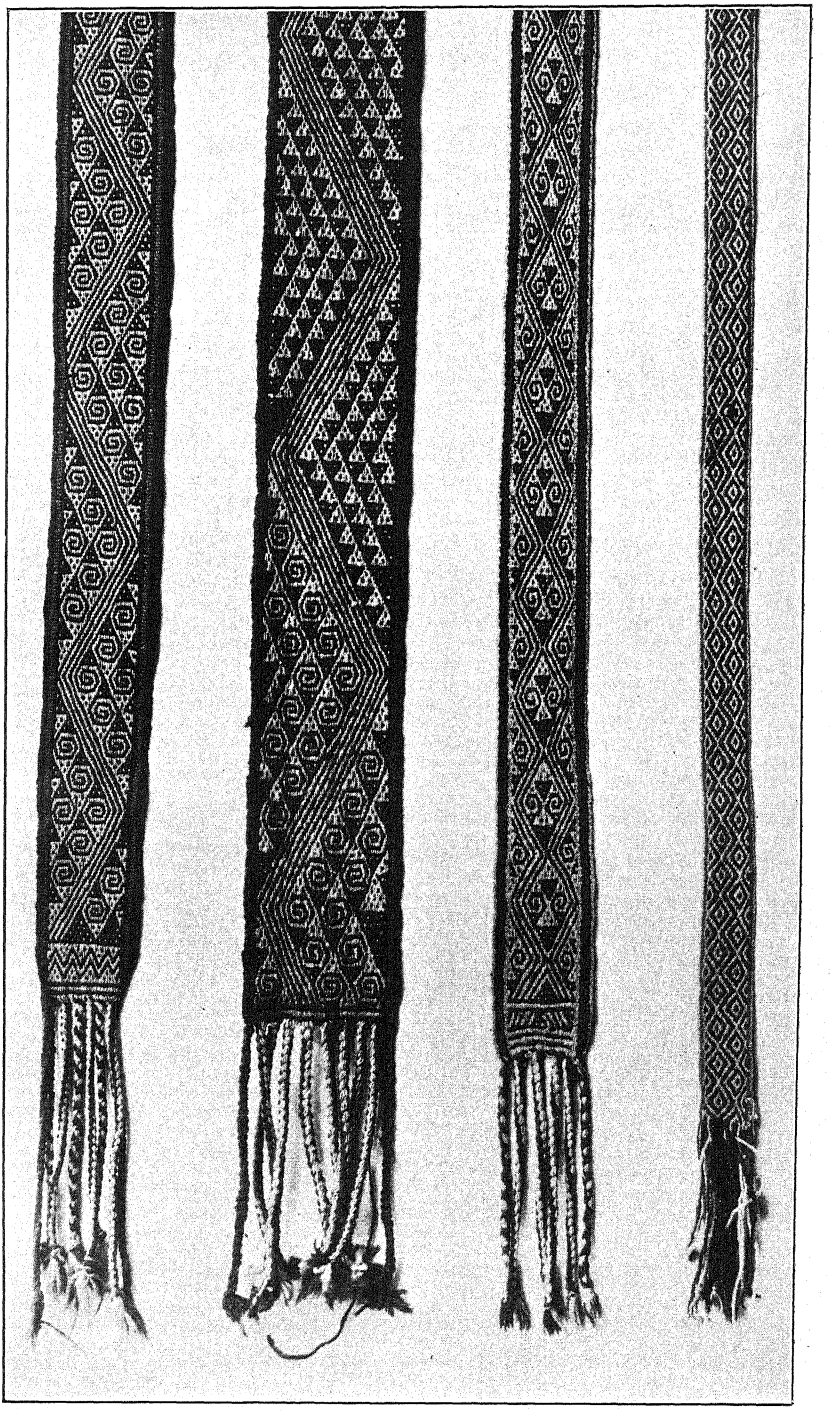
MEXICAN SERAPE (BELOW) AND DESIGNS FROM CEREMONIAL KILTS AND SASHES (ABOVE) OF THE HOPI INDIANS OF ARIZONA



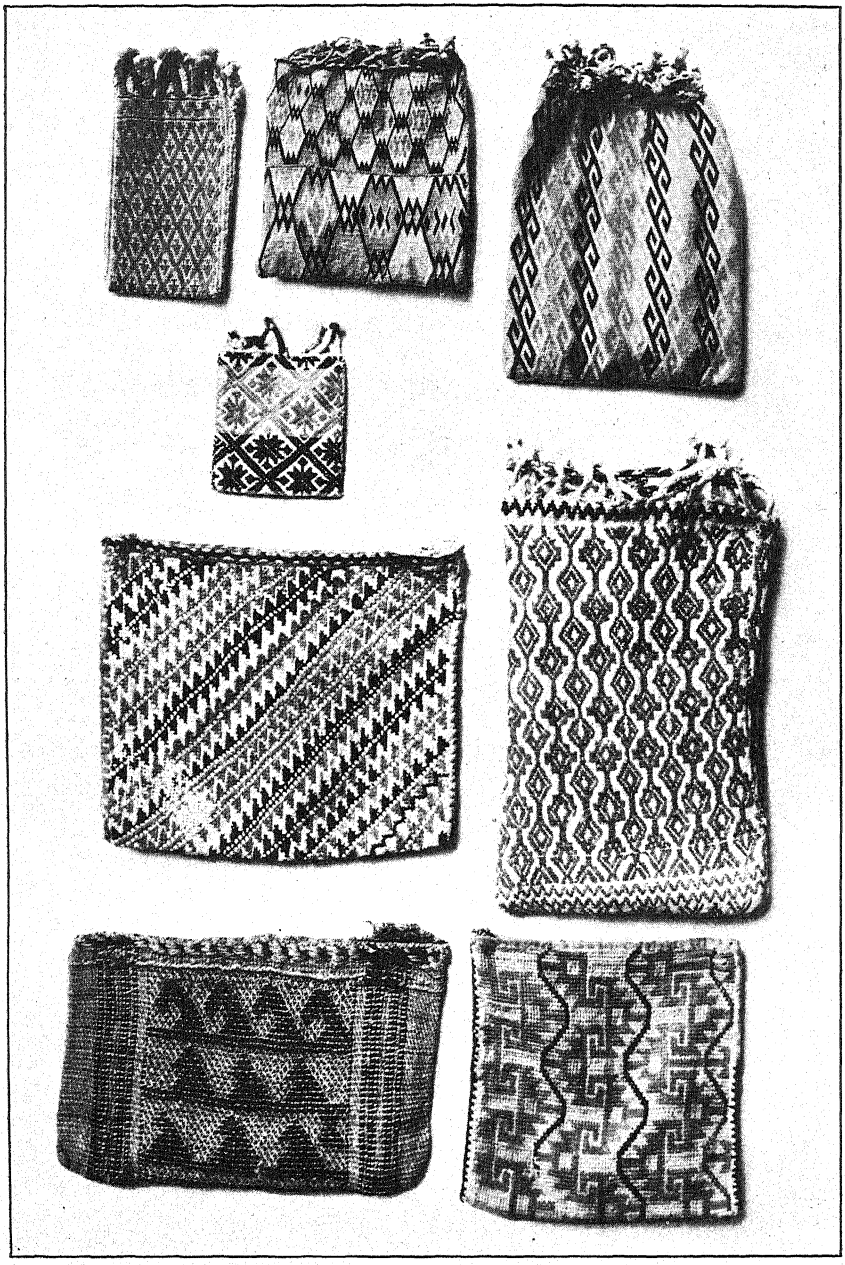
DECORATED EARTHENWARE ZUÑI JARS



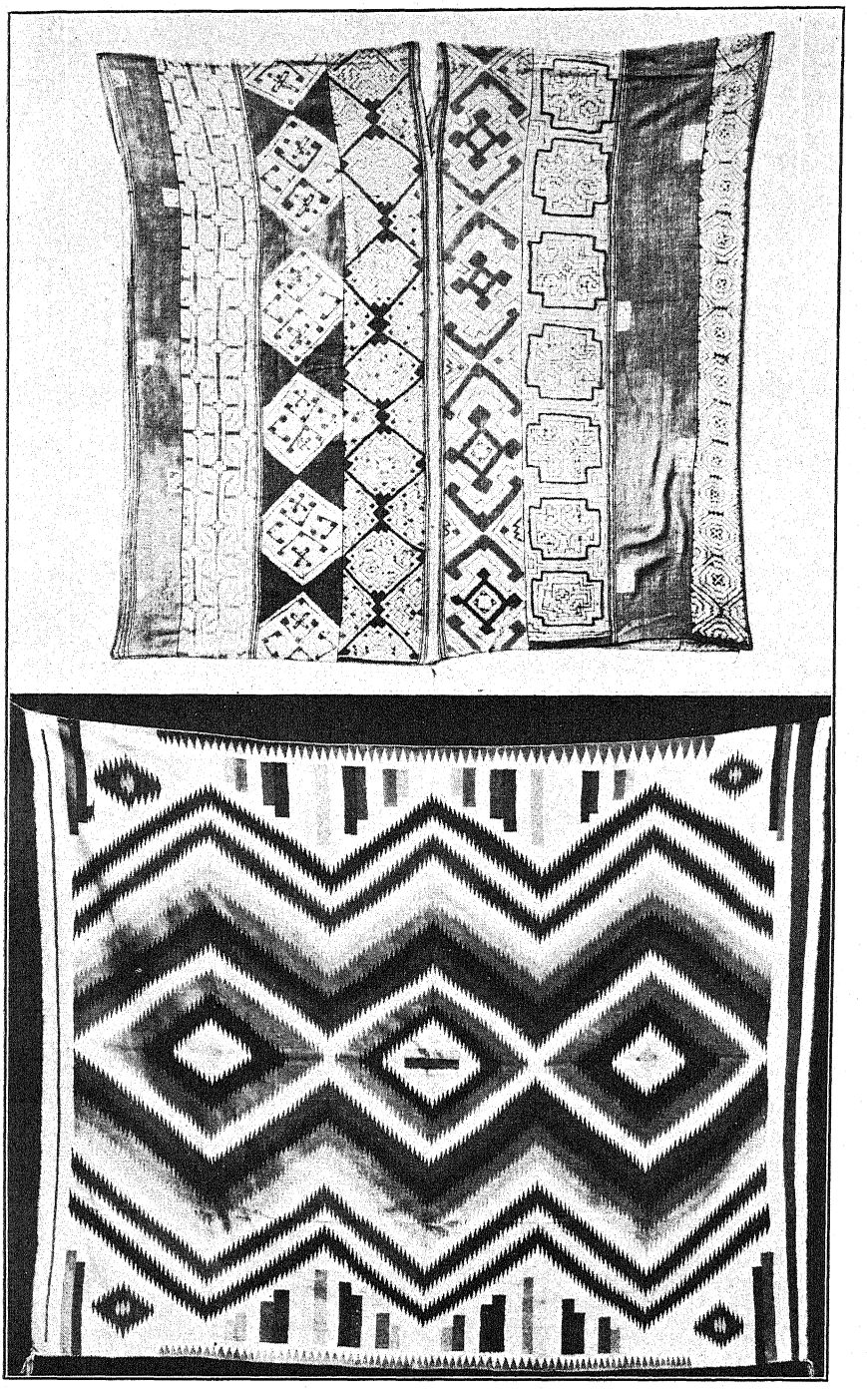
PICTOGRAPHIC DESIGNS PAINTED ON EARTHENWARE BOWLS, VASES, AND CANTEENS OF THE ZUÑI AND RIO GRANDE PUEBLO INDIANS



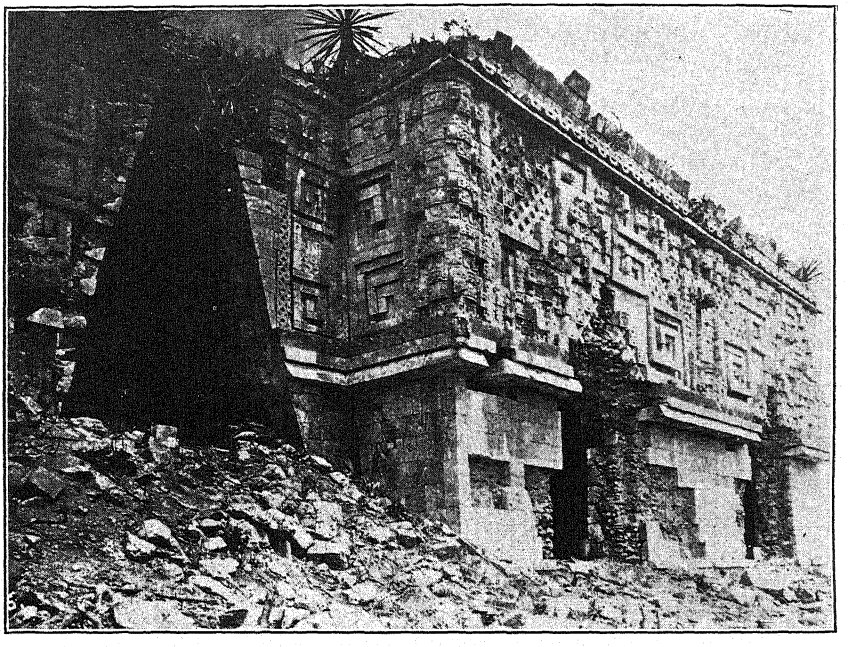
WOVEN BELTS OF THE CORA, HUICHOL, AND TARAHUMARE INDIANS, MEXICO

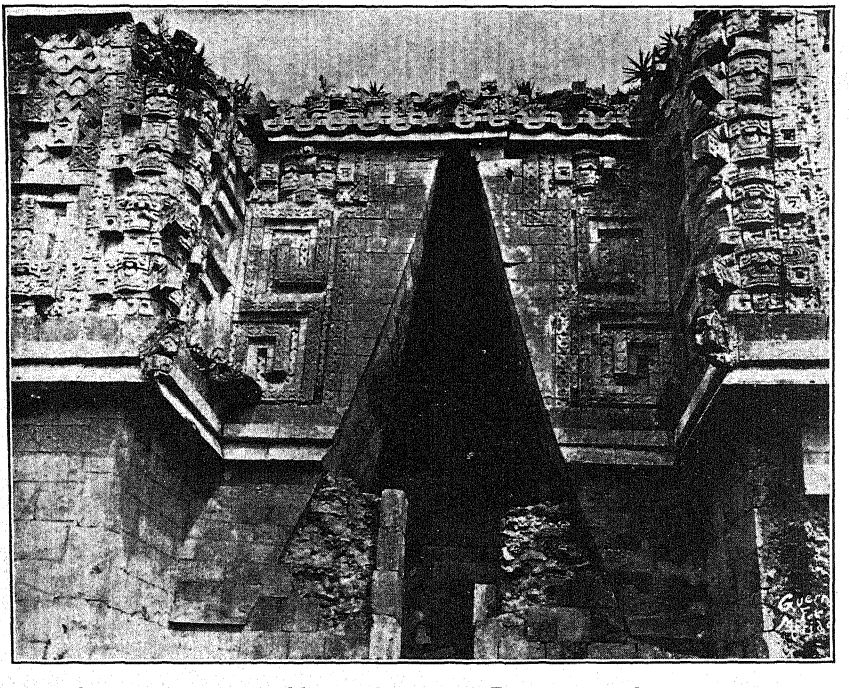


WOVEN BAGS OF THE CORA, HUICHOL, AND TARAHUMARE INDIANS OF MEXICO. A WOVEN MENOMINEE BAG IS SHOWN AT LOWER LEFT BY WAY OF CONTRAST



AN EXAMPLE OF PAINTED PIRO CLOTH (ABOVE). A WOVEN DESIGN OF THE NAVAJO (BELOW)





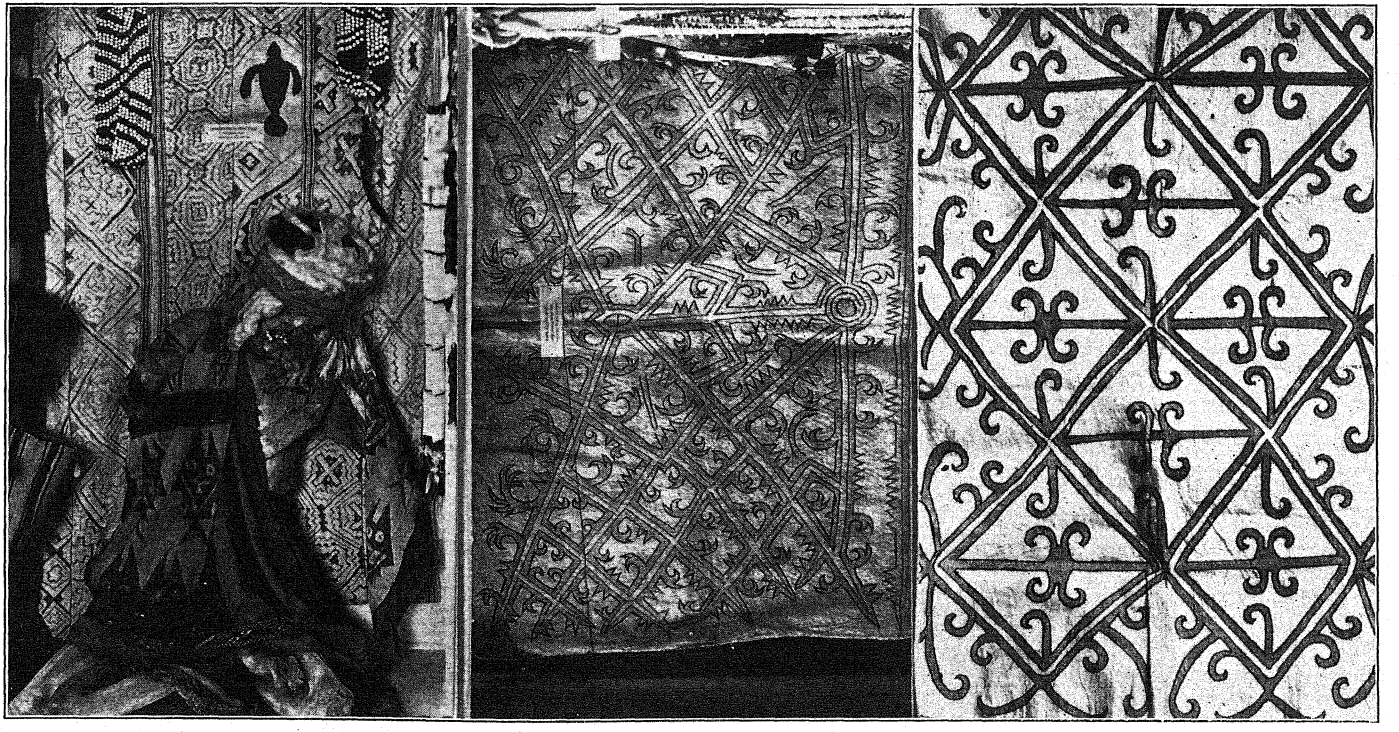
ILLUSTRATING THE MAYAN ARCH AND DECORATIVE ARCHITECTURE




CEREMONIAL FIGURINES OF THE CHOCO INDIANS OF SOUTHEASTERN PANAMA



ABOVE ARE SHOWN GUTTA-PERCHA ANIMAL AND BIRD EFFIGIES COLLECTED BY LIEUTENANTS HERNDON AND GIBBON FROM AMAZONIAN TRIBES IN 1856. BELOW IS A CEREMONIAL FIGURINE OF CARVED WOOD FROM THE PRE-



PERUVIAN TEXTILE DESIGNS. AN ANCIENT PERUVIAN MUMMY ENSHROUDED IN WOVEN COTTON CLOTH WITH STAMPED DECORATIVE DESIGN IS SHOWN AT LEFT; AT RIGHT, BARK CLOTH WITH PAINTED CURVILINEAR DESIGNS. INDIAN TRIBES OF THE UPPER AMAZON



1 2 3

1. BEADED SKIRT, JIVARO INDIANS, PERU; 2. SKIRT WOVEN OF HUMAN HAIR, PERU; 3. PAINTED DESIGNS ON ROBE OF TANNED COWHIDE. TEHUELCHE INDIANS, CHILE



WAR SHIRT DECORATED WITH EMU FEATHERS. INDIANS OF PARAGUAY

# THE ACCLIMATIZATION OF THE WHITE RACE IN THE TROPICS [1]

By Robert De C. Ward

The acclimatization of the white race in the Tropics is a question which is largely medical in many of its aspects. I wish to make it clear that I write wholly as a layman in so far as the medical side of my topic is concerned. The subject, however, also very distinctly concerns the climatologist. It is from the climatological, rather than from the medical, side that I propose to treat it. The problem is one the solution of which—if there be a solution— requires the close cooperation of medical men and of climatologists. The study of the physiological effects of tropical climates, and of tropical diseases, is the responsibility of the medical man. On the other hand, it is the business of the climatologist to set forth, in the greatest possible detail, all the characteristics of tropical climates, and, if the picture is not sufficiently complete or satisfactory for the purposes of the physician, to take steps to make it more so. While much work, and very excellent work, has been done by investigators of many nationalities, in many parts of the Tropics, there still remain great gaps in our knowledge which must be filled before our conclusions can be considered wholly sound, or final.

To my own thinking, there are few more interesting problems awaiting study on the part of medical investigators than those that relate to the physiological effects of tropical climates on white men and women, and especially on children. Such studies should by no means be limited simply to the ordinary physical changes in the body. They should especially be extended to cover the nervous system and the mental effects. Incomplete as our present knowledge of this problem is, it is nevertheless possible for us to present certain fairly well ascertained facts. It is these that I wish to consider, always remembering that the future may very considerably change our present views, and that many phases of the acclimatization problem are very recent. The attention of the medical profession has naturally and

[1] A lecture given at the Lowell Institute, Boston. The writer is indebted to Dr. Richard P. Strong for his kindness in reading the manuscript of this lecture, and for his helpful suggestions. Reprinted by permission from the New England Journal of Medicine, vol. 201, No. 13, pp. 617–627, Sept. 26, 1929.

properly been more concerned with the study of specific causes of tropical diseases than with the general physiological effects of tropical climates.

The acclimatization of the white race in the Tropics is a question of vast importance. Upon it depend the future settlement, control, government and utilization of the Tropics. It is becoming more important with the passing of the years. The increasing pressure of population in Europe demands an outlet. The need of an additional food supply in the not far distant future is turning our attention more and more toward the hot belt of the world. Tropical products, like coffee, rubber, quinine, spices, fruits, and lumber are desired in ever-increasing quantity. The land areas within the Tropics are to a large extent under the control of extra-tropical nations, as colonies, or protectorates, or possessions of one sort or another. The future more and more looks toward the Tropics. And what becomes of the Tropics is for the white man to decide.

This problem is of concern to many. It interests the statesman, whose responsibilities include relations with tropical countries; the economist, who concerns himself with laws of population and with food supply; the medical man, whose business it is to fight disease and to improve conditions of health all over the world; the climatologist, whose intimate study of tropical climates is essential to any thorough understanding of tropical problems; the engineer, geologist, or business man whose livelihood is to be gained in tropical countries.

The literature is already very extended. We Americans are apt to forget that people of our own blood, of the British Isles, have had many long years of intimate contact with the Tropics, and have made many important studies of the experience of their troops and of their civilians in hot countries. France has had her own dealings with the Tropics, in Africa and in the Far East. Germany, also, more recently, chiefly in Africa, accumulated information along the same lines.

One of the very natural misconceptions of a layman is that the climates of the whole tropical zone are in all respects alike. This is by no means the case. There are, in reality, three logical subdivisions of that zone: The equatorial belt, the trade wind belts, and the monsoon belts. In each of these there are modifications due to oceanic and to continental influences. Further, the effect of altitude is so important that another subdivision should be added to include mountain climates. All parts of the hot zone are not equally disagreeable or hostile, so far as occupation by the white race is concerned.

The tropical zone includes extended deserts over the continental areas in the latitudes of the trade winds; immense expanses of damp forests and jungles and swamp land in the vicinity of the equator;

fertile islands, refreshed by cool steady winds from the ocean; great grass lands with one season of drought and dust and another season of dampness, of rains, and often of floods; the monsoon districts, with their climatic control alternately that of the wet monsoon and of the dry monsoon; the mountains and plateaus with their lower temperatures and, if rising high enough, carrying snow the year around, even on the equator. This variety of climates makes it difficult to arrive at general conclusions for the lower latitudes as a whole. Each type of climate has advantages and each has disadvantages for the white settler. The deserts are free from many tropical diseases, their parched soil and dry, sterile air being unfavorable to the development and distribution of most microorganisms and of disease-bearing insects. Further, the general physiological effects of desert climates are stimulating. They do not have the weakening and enervating effects associated with the hot-house air of the latitudes nearer the equator. The drier districts are, on the whole, to be preferred to the moister. On the other hand, the dust and heat and brilliant sunshine are very trying, and the lack of water is obviously a serious limitation to settlement and agricultural development. Tropical deserts are "healthy" in the ordinary meaning of the term, but they are not desirable places of residence for white settlers.

Tropical islands in the trade winds, especially those toward the margins of the tropical zone, like the Hawaiian Islands, are generally regarded as far more desirable places of residence for white men and women than are the continental areas, especially those near the equator. Trade wind islands are still more desirable if they are mountainous, and therefore offer the advantages of tempered heat.

Wherever mountains and plateaus occur in the Tropics there is general agreement that the climatic conditions, at least up to a height of a few thousand feet, are more favorable for the white settler than are the hotter, damp lowlands. Altitude is chiefly important because of its effect in tempering the heat, especially at night. In India the hill sections are crowded during the hot months by civilian and military officials, and it has been well said that India is ruled from 7,000 feet above sea level. The climate of many tropical plateaus and mountains has the reputation of being a "perpetual spring." Thus, on the interior plateaus of the tropical Cordilleras of South America and on the eastern plateaus of Africa the heat is greatly tempered by the altitude, while the lowlands and coasts are very hot. A list of the better portions of the Tropics for white settlement always includes the plateaus of the Andes, of eastern equatorial Africa, and of South Africa; the Indian hill stations, and the Hawaiian and other trade wind islands. To this list, many other places might easily be added. Lord Bryce believed that Rhodesia will become the home of a settled British population, where the race will renew itself from

generation to generation, but the climate of this elevated region is very different from that of the hot and moist latitudes along the Equator. Yet tropical mountains and plateaus lack one feature of essential importance. They may, perhaps rightly, be said to have a "perpetual spring," but they lack distinct seasonal variety. They lack the tonic of a cold winter. Their temperatures are, it is true, lower than those nearer sea level, but although the temperature scale is lower, the same monotonous succession of notes is played upon it. They are temperate in the sense of having tempered heat. They are not "temperate" in the sense that they have temperate zone characteristics of distinct seasonal variety; of constantly fluctuating weather changes; of the alternation from warmer to colder winds, and from storm to fine weather. Tropical mountains and plateaus have monotony; a monotonous repetition of the same weather. That is the secret of their failure in solving the problem of acclimatization. They do offer immunity from certain tropical diseases. They fail to provide the "spur of the seasons" to which we are accustomed in temperate latitudes. The nonseasonal character of tropical climates—the so-called "perpetual spring"—is not by any means the best fitted for man's mental or physical development, however pleasant it may be for a time. Many tropical hill and plateau stations are beneficial in restoring those exhausted by overwork or by the heat of the lowlands. They are especially advantageous in the cases of white women and children. Nevertheless, climates temperate because of altitude can not replace climates "temperate" because of latitude.

In the problems of acclimatization and colonization in the Tropics our concern is chiefly, although not by any means solely, with the hot, damp, and rainy climates found generally in the latitudes near the Equator: The climates of the Amazon and Congo forests, for example; of the West Coast of Africa and of northern South America; of the typical tropical jungles; of the steamy oppressive "hot-house" type. It is in these more or less constantly wet climates that we find the wealth of tropical products which chiefly attracts the white man. It is here that, on the whole, there are the greatest possibilities for future food supply. The economic return is mainly from the damp lowlands, and not from the deserts or from the high plateaus and mountains. It is fairly safe to say that it is specifically the rainy low-latitude type of climate which promises the greatest potential agricultural resources, and also presents the most serious handicap to white settlement. It is with this climate that the problem of acclimatization is mainly concerned.

In the minds of most people the acclimatization problem is merely a question of whether a single white man or woman can live for a time in a tropical climate in reasonable comfort and with a fair

chance of good health. But the question is a far larger one than that. It concerns not one individual alone, nor even one generation alone. The real problem is this: Can men and women of the white race immigrate in large numbers to the moist hot Tropics and live there on the same high plane of civilization as that characteristic of their former homes, retaining their physical health and vitality, their mental and moral standards, and reproducing their own kind? Further, can future generations of white people, born in the Tropics, maintain, in the years to come, these same standards of civilization and of physical, mental, and moral vigor? This, it will be observed, is a very much larger, more complex, and more fundamental question, but it is the real crux of the whole matter. And this much larger question is, at present, very difficult, if not altogether impossible, to answer on the basis of known scientific facts.

The health relation of the white race in tropical climates is best considered from two points of view, first, the general one of tropical diseases, and second, the one that concerns the effects of physiological disturbances without always, or necessarily, involving specific disease.

It is not for the layman, without professional knowledge of medical science, to attempt any technical discussion of tropical diseases. He may, however, consider some of the obvious facts without committing himself in regard to details which do not properly fall in his own field of scientific study.

Certain diseases are so much at home in the Tropics that they have come to be known as tropical diseases. This designation does not imply that some of them may not, and do not, occur in extratropical latitudes when conditions of climate, traffic, unsanitary mode of life, absence of proper medical supervision, and so on, favor such occurrence. There is greater variety in tropical than in extratropical disease, but then, many diseases common in cooler latitudes prevail also near the Equator, and many are found in low latitudes which have been practically or altogether banished from higher latitudes. Again, certain diseases even in the Tropics, as is well known, e. g., in the case of yellow fever, have been hemmed in more and more by modern sanitary measures. Several conditions are at work in favoring the widespread prevalence and in determining the large number of tropical diseases. Among these three may here be mentioned: The agency of tropical insects and parasites in propagating or in transmitting the disease germ; the general weakening effect of the steady, damp heat upon the human body, and the excessively unhygienic modes of life of the natives. The tropical climate is not the sole, or even in many cases the determining factor, yet certain high temperatures are necessary for the occurrence and spread of malaria and yellow fever, for example, and the agency of the tropical fauna, whose requirements are the presence of known conditions of heat and of

moisture, is of fundamental importance in many cases. As the late Sir Patrick Manson pointed out, many years ago, in his famous work on tropical diseases, the term "tropical diseases" does not mean diseases confined to the Tropics. It was employed by him in a meteorological sense for diseases associated with, but not solely or even directly due to high temperatures. Tropical climatic conditions, per se, it may be noted in passing, probably do not injuriously affect the natives of the Tropics any more than do the conditions of extratropical climates affect us who live in them. Most tropical diseases attack both natives and whites; sometimes the former suffer most; sometimes the latter. There is no rigid hard-and-fast rule. The racial element is, however, often potent. Finally, great numbers of tropical natives have inevitably, in the long succession of generations, become more or less immune to the attacks of disease against which the whites have not yet developed immunity.

Leaving these broad generalizations, let us turn next to a brief consideration of a few of the more important tropical diseases. In addition to the more or less direct effects of exposure to tropical sunshine, dampness and heat, such as sunstroke, heat exhaustion and the like, there are malaria, and dysentery in various forms, doubtless the two worst enemies of white residents in the Tropics; sleeping sickness; tropical abscess of the liver; hookworm and other intestinal parasitical infectious fevers of different kinds; ulcers and other infections of the skin; many infectious diseases common to colder as well as warmer latitudes, and other ailments that chiefly attack the natives, and are therefore of a medical rather than of a practical interest in our present consideration. Yellow fever, cholera, and plague are very greatly limited, and are being more and more successfully overcome as the result of modern sanitary measures.

Twenty years ago Sir Ronald Ross wrote of malaria, "I venture to say that it has profoundly modified the history of mankind by doing more than anything else to hamper the work of civilization in the Tropics." During the two decades that have elapsed since that statement was made, the campaign against malaria has accomplished remarkable results, both in prevention and in treatment; yet it is safe to say that malaria still remains one of the most destructive diseases in the world. Rough estimates—the only ones that are possible at present—indicate that about one-third of the population throughout the Tropics suffers from it constantly. The malarial zone is a broad band within the moist Tropics, extending at times into the margins of the adjoining temperate zones. The disease is absent, or infrequent, in deserts and steppes, and on mountains at moderate elevations above sea level. It is perennial in its zone of maximum frequency, but has a general tendency to rise to a peak in the warmer or rainy season. Even in the early days of medical investigation into

the origin and conditions of malarial infection, a close relation between temperature and the occurrence of malaria was observed, so distinct that from then on the line of a mean annual temperature of 60° F. has been considered as marking the polar boundaries of recognized malarial infection, and winter cold has been seen to be the great barrier against the occurrence and spread of the disease. Rainfall is important because the malaria-bearing mosquito passes one stage of its life in water. Hence lakes, and especially marshes, pools, and swamps are critical as breeding places of the mosquitoes. Digging up the soil results in hollows where puddles and pools may collect. In early days, it was believed that stirring up the soil gave rise to certain noxious exhalations from the ground, and that these vapors or gases produced the disease. It is easy to see how that belief originated, and why it persisted until medical science wholly disproved it.

Tropical dysentery "slays outright, and makes miserable wrecks of white men in the Tropics," as a recent writer has put it, doubtless without exaggeration. Dysentery has its real home in tropical climates, and increases in severity and in frequency with approach to the Equator. Some form of it is always present in low latitudes, and it is there next in importance to malaria in causing high death rates, and in its lasting effects. In contrast with the case of malaria and of yellow fever, altitude can not be relied on to give relief. Residents on mountains sometimes suffer more than do those at lower levels.

The species of tsetse fly associated with sleeping sickness requires a warm, damp atmosphere, and the immediate presence of water. The limit of its altitudinal range is about 4,000 to 5,000 feet. It is found in the true equatorial forests where there is water, and also extends into the adjacent grasslands where there are groups of trees. Sleeping sickness occurs over a vast area in tropical and subtropical Africa. There it causes high mortality, a decreased birth rate, and is a serious menace to the existence of a large population. In consequence of its ravages, the labor supply is being diminished, and the economic development of the country is being retarded.

Because of its inevitable enervating and enfeebling effects, hookworm is another tropical and subtropical disease which is a very serious menace in many places. The economic loss is very heavy, perhaps even heavier than that caused by malaria. It has been estimated that between 60 and 80 per cent of the population of India harbor the parasite.

Yellow fever, formerly widely prevalent along the tropical shores of Latin America, and occasionally even invading our Gulf coasts, now has its last stronghold in western equatorial Africa, where such splendid work, unfortunately accompanied by the loss of valuable

lives, has been carried on for some years by the Rockefeller Institute for Medical Research. An outbreak of yellow fever in Brazil during the summer of 1928 showed that South America is not yet safe from this disease. Definite temperature controls over the occurrence of yellow fever have long been known, and stated in specific numbers of degrees of the thermometer scale, and the disappearance of epidemics when the freezing point is reached was noted several decades ago.

Sunstroke and heat prostration, as is to be expected, are most common in the Tropics. Exposure to the sun does not always explain sunstroke, for at sea the tropical sun is much less fatal than on land, and places with apparently similar conditions of sunshine differ much as regards prevalence of sunstroke. The story is told of a planter from Barbados who had gone to live in Madras, and who insisted on riding horseback in the sun as he had been accustomed to do in Barbados. He laughed at friends who warned him against running this risk, and lost his life by sunstroke. At Panama there were only two deaths from sunstroke and 21 cases of heat exhaustion in a population of 120,000, in 13 years. In Liberia, on the other hand, it has been pointed out by Dr. C. F. Brooks that in climatic conditions on the coastal lowlands much like those of the Atlantic coast of Panama, manual labor such as is performed by white men in Panama is impossible, and only a few minutes' exposure is enough to give "a touch of the sun." It has been suggested that an explanation may perhaps be found in the fact that in Panama protection against the sun is provided by a moist layer of air which extends to great heights, while in Liberia the moist layer is relatively thin. Very damp air, combined with strong sunshine, induces heat exhaustion at fairly moderate temperatures, and most damp lowlands in the Tropics are dangerous for white men who are doing manual labor, or who have their heads unprotected. Apparently, either intense sunshine alone, or very damp air alone, is not dangerous. It is the combination of the two that brings fatal results. On the wharves of Calcutta there used to be painted, in large white letters, the significant warning, "Beware of the sun," so that persons coming there for the first time from the British Isles would read those words before they set foot on shore. "Beware of the sun" is a good rule for the Tropics. There is, in general, too much sunshine in the Tropics. The skin of white persons exposed to the sun there often becomes badly burned and blistered, and travelers commonly suffer because of lack of protection of neck and limbs under the hot tropical sun.

The second aspect of the health and acclimatization of the white race in the Tropics concerns the physiological disturbances. While the separation of the effects of physiological disturbances from specific diseases is difficult, and may, from a strictly medical point of

view, even be impossible, nevertheless there is a line of demarcation between the two, however faint it may be, and however difficult it may be to draw.

The uniformly high temperatures of the Tropics—the well-known tropical monotony of heat—when combined with high humidity and the characteristically small variability of temperature from day to day, have certain already fairly well recognized physiological effects, although definite numerical measurements are still to a large extent not yet available, and much of the evidence is conflicting. On the basis of recent studies, the body temperature seems, in general, to be essentially the same as elsewhere when the body is at rest, but with exercise it rises more rapidly than in cooler climates, and also falls more slowly. Much exercise has the same effect as a mild fever. The respiration rate is high, probably because of the body's attempt to increase evaporation and so to reduce its temperature. There is evidence to indicate that evaporation from lungs and skin is far more concerned in controlling the body temperature than is chemical activity. The blood pressure apparently shows no permanent change, but there seem to be greater temporary variations after exercise than is the case in temperate climates. As regards the composition of the blood, there is a slight relative decrease in the number of red corpuscles, but the specific gravity shows no change except in disease. It appears that the popular belief in a "thinness of the blood" after prolonged residence in the Tropics is unfounded, except, as just stated, in the case of disease or of anemia. Perspiration is profuse. There is, in general, an increased activity of the liver, kidneys, and spleen, as contrasted with an increased activity of the organs of respiration in higher latitudes. It would seem that when the white man goes to live in the Tropics his first functional disturbances are likely to be in the intestinal organs, and may predispose to dysentery or other dangerous diseases. Per contra, when human beings or animals are brought from the Tropics to higher latitudes, where there are lower temperatures and greater variability of weather, the troubles which they experience are mostly pulmonary. It appears that, on the whole, the measurable physiological disturbances are not very significant, in so far, at least, as our present data go. There are, however, nonmeasurable nervous effects which may be much more critical and fundamental in the problem of acclimatization. Dr. B. C. Crowell, in an address before the American Philosophical Society, five years ago (1925), said, in speaking of the effects of tropical climates upon white men, "Science has not been able to measure the unquestionably harmful influence on the nervous system of a constant temperature, bright sunshine, brilliant colors, and the absence of seasonal variations."

The strain of residence in tropical climates seems to react distinctly unfavorably upon the nervous system of the majority of persons from colder climates, and, in the opinion of many medical authorities, it is just here that the greatest obstacle in the way of white colonization may be found. The muggy, oppressive "hothouse" air is not only uncomfortable and difficult to endure, but it has a distinctly enervating effect, which is more or less widespread among all white residents in the Tropics, and especially among women and children. Energetic physical and mental action are difficult, even impossible. "A depression of bodily and mental activity follows—enervation, indifference, disinclination to exertion, a general, ill-defined condition of debility." There is lessened power to do work, greater fatigue from work, lowered vitality. Dr. James Horton, an English physician, who was for some time stationed on the west coast of tropical Africa, reported that every continued mental effort in that climate was almost immediately accompanied by extreme fatigue and headache. While in England he could be actively at work 15 hours a day, he found that immediately on his return to the Tropics six hours was his extreme limit of continued activity and intellectual effort if he wished to avoid serious mental fatigue. An anemic condition is widespread in the moist Tropics. All this renders the body less able to resist disease. It is already weakened, and then the microorganism of some specific disease finds a fertile field for its ravages. The individual has largely lost his powers of resistance.

The monotony of tropical heat, together with a high degree of humidity, may produce the condition of neurasthenia so widespread among the white population of the Tropics, "a complex of symptoms produced by nerve exhaustion and often associated with, if not causing, an alteration in bodily nutrition." "It is this terrible nerve exhaustion," writes Dr. Havelock Charles, president of the Medical Board of India, "which has, in the past, been the most important factor in preventing the northern races from settling and procreating their line with a full share of the nerve vigor which the parental stock possessed." Tropical neurasthenia is not directly fatal, but it tends to create an emotional state of depression and to undermine a vigorous and healthy constitution. It prevents the development and maintenance of the *mens sana in corpore sano*.

The problem of acclimatization is not a question of climate alone. It is tremendously complicated by the controls exercised by race, diet, occupations, habits of life, and the like. The Chinese, for example, succeed where other people have failed. Indeed, so well do they thrive that there may, in the distant future, be more in "the Yellow Peril" than most people are willing to believe. The southern European is more successful than the northern European; the Latin

than the Anglo-Saxon. Those whose diet is light and simple fare better than those who are hearty eaters and much of whose food is meat. Excessive indulgence in strong alcoholic beverages is always injurious and dangerous. The Englishman who indulges freely in his brandy and soda in the hot Tropics is likely sooner to fall a victim to disease than is the Italian who drinks only light wines. Indoor occupations which keep people out of the sun are far more favorable than labor outdoors. Shopkeepers and clerks have, other things being equal, a better chance of keeping fit and well than do white policemen, or soldiers, or railway employees. Life in the Tropics, away from home associations and traditions and standards, is extremely likely to lead to the excessive use of intoxicating liquor, to lowered moral tone, to sexual indulgence, to a distaste for and avoidance of reasonable physical exercise; to an incorrect and poorly balanced diet. These, and other conditions, combine to make a normal, healthy life very difficult for most men from northern latitudes whose business takes them to the Tropics, and keeps them there for any considerable length of time. It is, of course, true that most of these handicaps to sane and healthy living can be overcome, but to overcome them takes more strength of will and moral backbone than many persons possess, and they remain as contributory controls in the general question of acclimatization. Dr. B. C. Crowell has pointed out that "the equilibrium of the white man's nervous system and his energy and initiative are disturbed by contact with impassive and at times stupid colored natives, by the tendency to the abuse of stimulants, and by the general lowering of the moral tone."

There is another factor in this great complex which one of my European colleagues has aptly termed "the climate of loneliness." It is psychological in its nature. It is found in every part of the world. The more socially inclined any individual is, the more significant is the rôle of "the climate of loneliness" in his case. It must not be lost sight of. It must not be confused with the ordinary climatic factors. It should be given weight—and sometimes tragically significant weight—as a contributing element in any discussion of the problem of acclimatization. How often has "the climate of loneliness" been the fundamental cause of the wreck—physical, mental, and moral—of the lives of young men and young women, whose breaking down, whose ill-health, and even whose deaths, were attributed to the tropical climate alone! "The climate of loneliness" is hard enough to bear at its best, in the climates to which one is accustomed at home. But it is in the deadening monotony of the steaming Tropics, far from home, that the real suffering which is caused by "the climate of loneliness" is experienced.

As compared with the death rates in colder latitudes, tropical statistics of mortality average high. These death rates, however, represent

such very diverse conditions of season, climate, race, occupation, soil, mode of life, food, dwelling, etc., that they can not properly be compared with one another. The prevalence of some special disease in exceptionally virulent or widespread development will raise the death rate of any one year far beyond its normal figure. Again, the presence of some plant disease or pest which causes loss of crops, and the resulting lowered vitality of the people in consequence of insufficient food, may easily swell the death rate. Nowhere can these tropical death rates properly be compared with those noted under different conditions in other latitudes. Most of the reliable statistics of mortality relating to white men in the Tropics are for soldiers, that is, men, in the prime of life, subjected to rigid discipline; provided, when possible, with carefully selected food, proper living quarters, and adequate medical and sanitary supervision. Obviously, death rates for white soldiers in the Tropics are not directly comparable with the death rates in our own country, which include all ages, both sexes, and very diverse living conditions, as well as deaths by accident and old age. So various and so complex are the controlling factors that critical comparative study is not worth while. Some years ago I was asked to present a paper on tropical death rates before a scientific body, but I declined the invitation on the ground that such a discussion was really not a profitable one.

Tropical death rates are certainly high, but this fact should not be attributed solely to the dangers of the climate. Bad sanitary conditions and lack of medical attendance account for many, if not most, of the high mortality rates among the natives; and an irrational mode of life explains many deaths among persons coming from cooler climates. Tropical death rates have been, and are being, reduced with remarkable rapidity in all countries which are wholly or partly under white control, and especially among white troops in the Tropics. This is the result of experience with tropical conditions, and of the increased precautions that are now taken in selecting and caring for the men.

The death rates among white people in the Tropics range from the appalling figure of 483 per thousand among European troops on the Gold Coast of Africa in 1829–1836—almost every other man died—down through steadily lower figures until we come to a rate as low as 5 per thousand for the British troops in India in recent years. A few illustrations of the change may be given. A death rate of 115 in French Cochin China in the 1860's had been reduced to about 20 per thousand in the later 1870's and early 1880's. Among Dutch white soldiers in Java the rate of 170 in the second and third decades of the nineteenth century had been lowered to less than 20 in the last decade. Very striking, also, has been a phenomenal reduction in the death rate from dysentery among the Dutch troops

in Java, from 13 per thousand in the 1870's to less than 1 per thousand in the 1880's, a decrease attributed to the avoidance of contaminated water as the result of the use of artesian wells.

The mortality rate of the British Army in India has fallen from over 80 per thousand in the early decades of the nineteenth century, successively, in later periods, to under 60, under 20, under 10, and even to 5 in the most recent years. In Ceylon, reckoned as one of the most unhealthy stations, the rate was over 110 and is now about 7. In western equatorial Africa, formerly known as "the white man's grave," the terrible figure of earlier years has fallen to a fraction of the former rate. Such statistics are clear proofs of the notable triumphs of medical science and of military organization. In many former wars, for one victim claimed by a bullet, an arrow, or a spear, four or five victims, even perhaps nine or ten, were claimed by disease. The records of the Crimean War and of the Boer War furnished striking evidence of this fact. Our own record in the war with Spain was not one to be proud of. Encouraging as is this remarkable reduction in tropical death rates, it should be observed that, as the Indian Medical Record pointed out some years ago, "The lowered death rate in hot countries is not evidence in favor of acclimatization, but, on the contrary, it shows that this low rate is only reached after the taking of most elaborate precautions. It is rather a proof of the inability of the white race to colonize in the Tropics, i. e., to labor and undergo exposure there. It is absurd to say that a reduced death rate, directly due to the careful avoidance of every possible exposure, is an evidence that such exposure can be endured." Furthermore, it is but natural that large numbers of white soldiers, and of civilians also, are if possible invalided home to cooler climates as soon as it is discovered that recovery will be slow, or difficult, in the Tropics. It thus results that many invalids, in cases where they do not recover, have died on the voyage back, or at home, and their deaths do not figure in the tropical death rates. I have seen statistics, authority for which I am unable to give, that in a fairly recent year the death rate among a certain group of European troops invalided home, or discharged, was over 50 per thousand.

In general, as I see it, no statistics of tropical mortality can be a true index of health conditions there for the reason that many tropical diseases, not necessarily or highly fatal, leave their victims in a weakened and debilitated condition. In addition to those who die of disease, there are many who become wrecks of their former selves and are unable to carry on. The economic loss resulting from this condition is necessarily a very great handicap.

In considering tropical diseases in relation to acclimatization, the thought inevitably arises in one's mind whether, with the eventual elimination and eradication of the major tropical diseases, the prob-

lem of acclimatization will not be solved. No one can read of the wonderful progress that has been made in the fight against yellow fever, malaria, hookworm, and dysentery, without looking to the future with high hope of a continuing and eventually a complete conquest. The work of General Gorgas at Panama, in reducing the death rates from 40 per thousand to 7.5, a year or so later, is certainly an object lesson in successful prophylaxis. It is one of many "monuments of victory," as these splendid achievements in the war on tropical disease, in Panama, in Cuba, in the Philippines, and elsewhere, have well been called. It has been estimated that in the Malay States, over 30,000 lives were saved by the introduction of an adequate drainage system. Fifty years ago the death rate in Jamaica averaged over 50 per thousand. It has now been reduced to nearly that in our own cities. A brilliant group of medical men—heroes, all of them, and several of them martyrs to medical science—has accomplished almost incredible results. The areas ravaged by some diseases have been limited. "Quinine, kerosene and mosquito netting" have accomplished wonders. The future certainly looks bright. Many diseases associated, directly or indirectly, with tropical heat and moisture can now be effectively guarded against by the intelligent and persistent observance of simple rules of living. Medical science already knows, fully or partially, the best methods of controlling and preventing such diseases as plague, cholera, yellow fever, typhus, malaria, sleeping sickness. As a recent medical writer has put it, the question of how far to apply this knowledge in a practical way is now very largely one of expense and of incentive.

In this discussion certain facts seem to stand out in the mind of a layman. Tropical diseases are still, and will for generations remain, a very serious handicap to white settlement of the Tropics. Medical men will doubtless be the first to agree that a great deal of slow, patient scientific research must still be accomplished before the fight against the widely extended strongholds of many tropical diseases can be successfully carried through. Sanitary campaigns, on a vast scale, must be undertaken. These are immensely expensive, perhaps for generations to come prohibitively expensive. And they may also be very difficult because of the ignorance and opposition of the natives. To quote, "Those who are not actively engaged in the war against tropical disease are not given to exuberant optimism concerning the outlook, but are preparing for a conquest 'which must be sustained with method and tenacity' for years to come." The brilliant work accomplished in Cuba, in Panama and elsewhere, in the fight against yellow fever, involved a very large expenditure of money. The area was limited. There was strong military or civilian compulsory authority behind it. If one looks at the extent of the wet Tropics on any map of the world's climates, the impos-

sibility of carrying through any such campaign over the whole of that vast area will be obvious at one glance. Yet, in spite of all these difficulties, the advance that has been made within the last few decades inevitably leads us to hope that eventually life may be as safe from disease in the inner Tropics as it is in our own home climates.

In view of the large number of factors involved in the problem of acclimatization, and of the very incomplete state of our knowledge on the subject, it is not surprising that the opinions of writers differ very markedly from one another. There is, on the one hand, the group which takes a distinctly pessimistic view, and sees practically no hope whatever. Those who belong in this group are mostly men who expressed their opinions many years ago, before the days of the modern study of tropical medicine and of tropical sanitation. In the second category we find those who believe that acclimatization is merely a question of overcoming disease; who look forward to a rapid elimination of all tropical diseases, and who do not regard the effects of the physiological disturbances of any special significance. Writers of a third group fully recognize the progress made in the warfare on tropical disease but do not, even in their most optimistic moments, see the disappearance of tropical diseases which are such a tremendous handicap to white settlement in the Tropics. They believe that, entirely apart from the presence or absence of disease, hot, damp tropical climates have a deleterious influence upon white men, especially upon white women and children, which operates and will operate as an apparently insuperable obstacle to the complete acclimatization of our race in the Tropics.

It will help to understand the views of these three groups of writers if we quote briefly. Alfred Russell Wallace held the view that true acclimatization is impossible. "An Englishman," he said, "who can only live in Rome by sleeping in a tower and never venturing forth at night can not be said to be truly acclimated." The older generation will easily remember the days when cautious travelers in Italy never accepted a room on the ground floor of a hotel, and always came in before sunset. Those were, of course, the days when malaria was rampant on the Roman campagna, and experience had shown that what was called "Roman fever" was "caught" oftenest by those who were out in the evening, and who had rooms near the ground. The correct explanation is, of course, to be found in the fact that the malaria-bearing mosquito is nocturnal in its habits, and usually does not fly far above the ground. Those were the days when life on the equatorial west coast of Africa was a very dangerous and uncertain business. The doggerel, "the Bight of Benin, and few come out that ever go in," was a common way of expressing the serious risk of landing in the Bight of Benin, the body of water

off the Slave Coast of Africa. It was a popular saying at that time that every British colony on the west coast of Africa had three governors, one on his way out on a steamer to assume his post of duty, one still carrying on the government of the colony, and the third on his way home in the handsomely appointed coffin which the government had provided for him. In The Control of the Tropics published in 1898, Benjamin Kidd wrote: "The Tropics * * * can only be governed as a trust for civilization, and with a full sense of the responsibility which such a trust involves. The first principle of success in undertaking such a duty seems to the writer to be a clear recognition of the cardinal fact that in the Tropics the white man lives and works only as a diver lives and works under water. Alike in a moral, in an ethical, and in a political sense, the atmosphere he breathes must be that of another region; that which produced him and to which he belongs. Neither physically, morally, nor politically, can he be acclimatized in the Tropics." Kipling put much the same idea into verse:

"And the end of the fight is a tombstone white
With the name of the late deceased,
And the epitaph clear, 'A fool lieth here
Who tried to hustle the East,' "

Of India, Meredith Townsend in his book, "Asia and Europe," made the following significant statement: "Not only is there no white race in India; not only is there no white colony, but there is no white man who proposes to remain. No ruler stays there to help, or criticize, or moderate his successor. No successful white soldier founds a family. No white man who makes a fortune builds a house or buys an estate for his descendants. The very planter, the very engine driver, the very foreman of works departs before he is 60, leaving no child, or house, or trace of himself. No white man takes root in India."

There is a practically universal conviction on the part of white residents in the Tropics that they need to renew their strength and vigor by going back to their home climates at frequent intervals, unless they wish to wear themselves out, and some day succumb as hopeless wrecks. For white children, especially, a long residence in the Tropics is highly undesirable. One competent authority says: "As a matter of fact there is a constant stream of invalids sent home from all tropical climates, and omitting a few dissenters, there is a generally accepted opinion that two years is the longest period it is safe to remain in hot places without a more or less prolonged vacation in a cold country." A surgeon who had long experience in the Tropics says that the limit of endurance of an equatorial climate, even on an island, and for a strong man, is

seven years. An American Army medical officer has stated that the most energetic and stalwart Americans after a year of service in the Philippines lose energy, strength, and ambition. I have a copy of a letter written by an English judge who had long been a resident of Ceylon, in which he emphasizes the tragedy of sending the children back to England. He writes. "Surely for us there is no climate like our own. And when all is said, in a tropical climate, even of the best, we live as it were on sufferance, and the climate tells on the next generation. For every one of us who has his livelihood in Ceylon, there comes the inevitable day when he must part from his children and send them home. This stern necessity has been styled a price which we pay for our Eastern possessions—and a heavy price it is."

The second group of writers says, in brief, "The conquest of the Tropics is not yet an accomplished fact, but enough has been done to show that most or all of the disabilities of the climate can be overcome. The Tropics are not unhealthy because of any effects of the climate, but because of the diseases peculiar to the Tropics. Many of these are now preventable; the others will soon be so. With their disappearance, the countries formerly thought deadly for white men and women have actually come to be almost salubrious. Most, if not all, of the difficulties are due to such factors as intemperance, improper food, sexual indulgence, the proximity of inferior races, and the like. These are handicaps, but they can be overcome. They are secondary and indirect climatic effects, and will disappear. The acclimatization problem is rapidly nearing its natural solution."

Such optimism seems, to me at least, beyond the bounds of reason. That the elimination of some tropical diseases has made a tremendous change for the better in certain parts of the Tropics no one will deny, but that effects of the physiological disturbances remain, and the happy future forseen by these enthusiasts is not yet in sight, is equally true.

The views of the third group are intermediate between those of the first two categories. There is, in the minds of most writers on acclimatization, the conviction that even if all tropical diseases could conceivably be eliminated from the picture, there would still remain those insidious physiological effects of the tropical sun, the heat and the humidity already referred to; the general physical, mental, and moral deterioration; the neurasthenia; the inability to maintain full bodily and mental vigor. In the present stage of our knowledge, true acclimatization is considered impossible, and while, with proper precautions, individual white men can live in the Tropics, the race can not persist. This thought, Dr. Andrew Balfour, director of the London School of Hygiene and Tropical Medicine, has recently

stated as follows: "So far as the race is concerned, I am persuaded that the hot and humid Tropics are not suited to white colonization and never will be with our present knoweldge, even if they were rendered as free from disease as England." The same idea was expressed by Dr. John C. Phillips, in an article in the Harvard Alumni Bulletin, four years ago: "I doubt whether the white man can ever escape the ultimate effect of the Tropics (particularly the mental effect) merely by living at high altitudes. He may well escape all tropical diseases, but there are subtle deteriorating influences that will finally come upon him unless there are regular and extended visits to the homeland." Some few years ago I wrote to the editor of one of the leading English medical journals, the Lancet, asking him to state briefly what he believed to be the views of the medical profession in his country on the question of acclimatization in view of the long experience of British soldiers and civilians in tropical countries, especially in India. It should be remembered that much of India and of other monsoon areas, especially during the rains, have conditions of heat, moisture, and rainfall very similar to those of the low altitudes near the equator. The answer to my request was an excellent editorial in two successive issues of the Lancet, giving considerable detail, and summarizing the conclusions briefly in the following statement: "That residence in hot climates under the circumstances of ordinary life has an adverse effect upon Europeans can not, we think, be doubted. Some constitutions seem to be altogether unfitted for these climates, and such individuals lose their health and physical energy from the moment of their arrival. A still larger number do so sooner or later under a more protracted residence, even if they escape being attacked by one or the other of the endemic or epidemic diseases incidental to such climates. Residence in tropical and subtropical countries usually produces a very appreciable effect, not only on the complexion but on the constitution, and notably so during childhood and youth."

Such quotations might be extended almost indefinitely, but those that I have given are representative. It is obvious that there are real differences of opinion as to the effects of tropical climates. The truth lies somewhere between the extremes; between the older pessimistic and newer optimistic views. The Tropics are not as hopelessly unhealthy as they have been painted. On the other hand, they are not, for the large majority of nonnatives, a desirable place of residence. To sum up this highly complex matter: White residents from cooler latitudes on coming into the Tropics must adjust themselves physiologically to the new climates. During this adjustment there is more or less strain on various organs and functions of the body. The strain may be too severe; then the individual suffers. The

adjustment is usually greatly retarded and hindered by a persistence in habits of food, drink and general mode of life which, however well suited to the home climate, do not fit tropical conditions. During the adjustment, especially if complicated by irrational habits, the body is naturally abnormally sensitive to the new diseases to which it is exposed. Even should no specific diseases be contracted, there are anemic and neurasthenic tendencies and other degenerative changes. Experience teaches that white men can not with impunity do hard manual labor under a tropical sun, but that they may enjoy fairly good health as overseers, or at indoor work, if they take reasonable precaution. Acclimatization in the full sense of having white men and women living for successive generations in the Tropics, and reproducing their kind without physical, mental, and moral degeneration—i. e., colonization in the true sense—is impossible. Tropical disease and death rates, as has been abundantly shown, can be much reduced by proper attention to sanitary laws, so that these rates may become not much, if any, higher than those in the extra-Tropics. And with increasing medical knowledge of the nature and prevention of tropical diseases, as well as by means of modern sanitary methods, a white resident in the Tropics will constantly become better able to withstand disease. It can not truthfully be said that scientific investigation has shown that climate is an *insuperable* obstacle to the white man's residence in the Tropics. Further investigation is, however, very greatly needed. As Sir Patrick Manson expressed it, acclimatization is less "an unconscious adaptation of the physiology of the individual" than "an intelligent adaptation of his habits." For greater comfort, for better health, and for greater success, properly selected hill stations will, however, always be essential to northerners who have to live in the Tropics, especially to white women and children.

It has been said, I believe by General Wolseley, that the white soldier in the Tropics is "always in campaign, if not against the enemy, at least against the climate." This sentence may be made to fit the case of the white civilian by changing it to read: The white race in the Tropics is always in campaign against its enemy, the climate.

What of the future? There will be a slow and limited settlement of the most favorable portions of the Tropics by nonnatives, who will construct houses suited to the conditions: Large, well-ventilated and artificially cooled, and well exposed to free-moving air. Electrical appliances of all sorts, for cooking, for refrigeration, for ventilation, will prove a tremendous boon to those whose lot is, in the future, cast in hot tropical climates. Proper clothing, modern sanitary measures, good hygiene—all will prove increasingly im-

portant. There is no doubt that civilized man can cope with tropical conditions and problems far more successfully than can the native. The white man can live there, but he needs intelligence and a rigid discipline in order to do so successfully. His mode of life must conform to the climate. He should not expect that his internal physiological adjustments will make him independent of his environment. "Toleration of climate is one thing; independence of it is quite another." Life in the Tropics will, in the future, certainly become more comfortable as well as safer for the white race, but in the light of our present knowledge, acclimatization, in its full and literal sense, is and will remain impossible.

# THE EIGHTH WONDER: THE HOLLAND VEHICULAR TUNNEL[1]

By CARL C. GRAY and H. F. HAGEN[2]

[With 30 plates]

Back in the second century B. C., a certain Antipater of Sidon composed an epigram in which he enumerated what he termed the "Seven Wonders of the World." They were the walls of Babylon, the statute at Olympia by Phidias, the hanging gardens at Babylon, the Colossus of Rhodes, the pyramids of Egypt, the mausoleum at Halicarnassus, and the temple of Artemis at Ephesus.

To-day any similar list of wonders, no matter by whom compiled, would doubtless include the pyramids, not merely because they alone have survived the ravages of time, but because they still represent a marvelous achievement of man's handiwork. What the other wonders would be might afford material for a contest sponsored by some newspaper columnist. But surely there would be a place in such a list for the Holland Tunnel, as the longest subaqueous tunnel in the world, a stupendous project, magnificently conceived and executed. And surely old Antipater himself, however wedded he might be to his own wonders, would to-day be glad to add the Holland Tunnel to his list, as an eighth wonder of the world.

It is with this belief that the following record of its history has been written, in recognition of the magnitude of the task, of the heroism of its first chief engineer, Clifford M. Holland, and his successor, Milton H. Freeman, both of whom gave their lives to the undertaking, and of the great advance in the science of ventilation which its construction made possible.

Of course, a tunnel is no new thing. Primitive man, living close to nature, could hardly have failed to observe evidences of tunneling by animal life about him, and soon made tunnels for his own purposes. We know that in ancient Egypt a king, upon ascending the throne, began at once to excavate the long narrow passage leading

[1] Reprinted by permission, with a few omissions from a pamphlet entitled "The Eighth Wonder," published by the B. F. Sturtevant Co.

[2] Grateful acknowledgment is made for valuable data obtained from the official reports of the New York and New Jersey Tunnel Commissions and from the Engineering News Record, and for permission to reprint a portion of an article from the magazine Charm, published by L. Bamberger & Co., Newark, N. J.

to the rock-hewn chamber at Thebes which was to be his tomb. From Egypt, too, comes the first record of a subaqueous tunnel—construct-

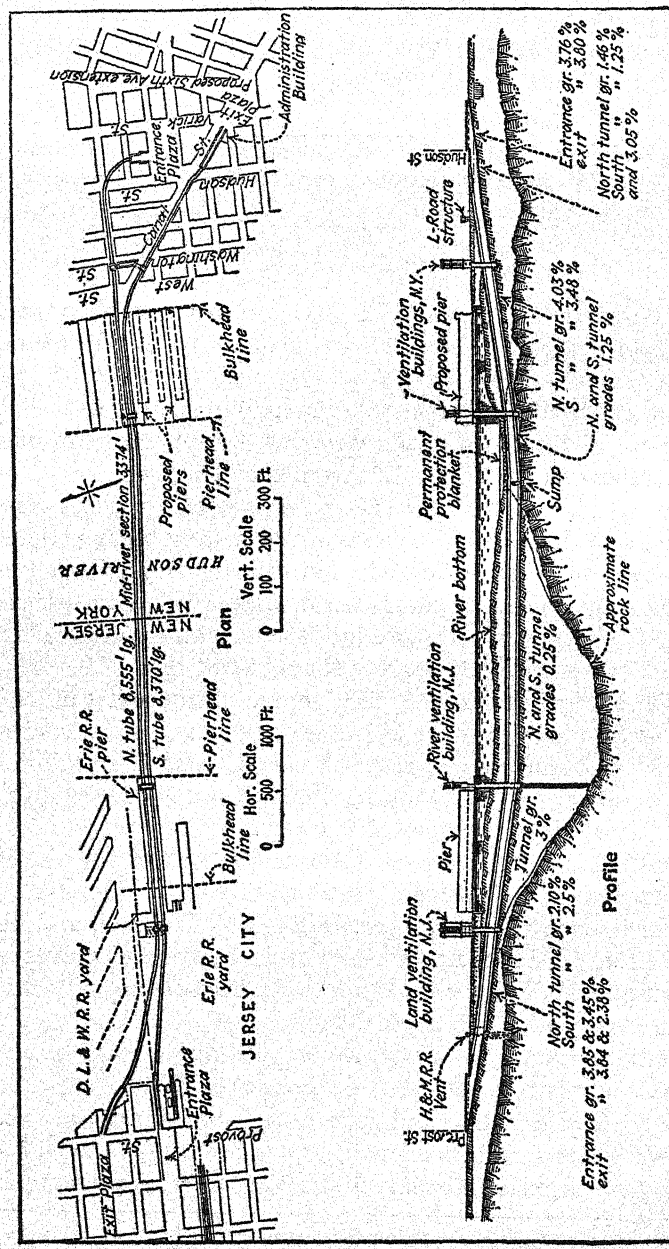



FIGURE 1.—Plan and profile of the Holland Tunnel

ed under the dry bed of the river Euphrates, which had been temporarily diverted from its channel. It was 12 feet wide, 15 feet high, and was lined with brick masonry.

In the time of Caesar Augustus, or perhaps even earlier, the Romans built a notable tunnel through the Posilipo hills, between Naples and Pozzuoli, about 3,000 feet long and 25 feet wide. In order to light this tunnel, its floor and roof were made to converge gradually from the ends to the middle: at the entrances it was 75 feet high. The Romans were the greatest tunnel builders of antiquity. During the Middle Ages tunnel building was chiefly for military purposes. Every great castle had its private underground passage from the central tower or keep to some distant concealed place, through which to make sorties, receive supplies, or escape in time of need.

With the advent of gunpowder and of canal construction, a strong impetus was given to tunnel building in its more modern aspect of commercial or public utility. Previous to 1800, canal tunnels were all through rock or hard ground. Then, in 1803, a soft-ground tunnel 24 feet wide was excavated for the Saint Augustine Canal in France. Timbers were laid to support the roof and walls as fast as the earth was removed, and the masonry lining built closely following. From this experience the various systems of soft-ground tunneling since employed have developed.

The use of shield and metal lining marks the greatest development in the art of soft-ground submarine tunneling. The shield was invented and first used by Sir Marc Isambard Brunel in excavating the first tunnel under the river Thames at London, begun in 1825 and opened in 1843. In 1869 Peter William Barlow used an iron lining in connection with a shield in driving the second tunnel under the Thames at London.

The modern tunnel shield is a steel-plate cylinder whose forward edge acts as a cutting edge. Its rear end, extending backward, overlaps the tunnel lining of cast-iron rings. Inside the shield, hydraulic jacks act against the tunnel lining as a thrust block so as to push the shield ahead when pressure is applied. A partition prevents earth from entering the shield except as permitted through suitable openings. As the shield moves forward, the lining is erected under the protection of its rear. In submarine tunneling compressed air pumped into the forward end of the tunnel counterbalances the pressure of the water which tries to enter.

In 1906 the Legislatures of the States of New York and New Jersey created for each State a bridge commission to investigate the feasibility of constructing a bridge over the Hudson River, uniting New York City with Jersey City. Legislative recognition was thus given to an increasingly vital problem—some means to supplement the ferries plying between these two ports.

Further legislation, enacted from time to time, continued the life of these commissions. In 1913 they were authorized to consider the possibility of a vehicular tunnel. Finally, on April 10, 1919, author-

ity was granted them to proceed with the construction of a tunnel, or tunnels, between a point in the vicinity of Canal Street on the island of Manhattan and a point in Jersey City.

Those who had the project closest at heart felt that the tunnel would

1. Shorten the time of transit across the Hudson River and afford a continuous means of communication between New York and New Jersey, unaffected by climatic or other interference.
2. Relieve traffic congestion, already serious.
3. Accelerate the movement of necessary supplies into the city of New York, and thereby relieve conditions of distress.
4. Increase the tax value of real property within a considerable radius of the tunnel terminals.
5. Pay its cost three times over within 20 years.
6. Reduce the high cost of living by reducing the cost of trucking.
7. Increase the facilities for commerce in the port of New York by removing from the surface of the harbor many lighters and other floating equipment.
8. Furnish means for the uninterrupted movements of troops and supplies to and from the city of New York in case of need.

The commission selected as chief engineer, Mr. Clifford M. Holland, tunnel engineer of the Public Service Commission, First District, State of New York, in immediate charge of the construction of all subway tunnels under the East River. He was regarded as having had a greater and more successful experience in the work of subaqueous tunnel construction than any other member of his profession. A board of consulting engineers was appointed, and a contract or treaty between the two States was drawn up and approved by the commissions and given the consent of Congress.

Chief Engineer Holland took office on July 1, 1919, and at once began the organization of an engineering staff. His chief assistants were selected from those who had been associated with him in the construction of the East River subway tunnels. Having had not less than 10 years' experience in subaqueous tunneling, they were well qualified both by technical training and by practical experience to meet the requirements of the work. Actual construction began October 12, 1920.

Upon the death of Mr. Holland on October 27, 1924, at Battle Creek Sanitarium, where he had gone in search of health after devoting all his strength and energy to the construction of the tunnel, the commissions gave it his name. Under his direction all the more difficult portions had been completed and the remaining details planned, and on the very day his body was borne to his home there came a demonstration of his engineering skill and accuracy in the successful junction of the under-river headings of the north tunnel.

His successor, Mr. Milton H. Freeman, had been his division engineer. He, too, gave himself unsparingly to the work, and died on March 24, 1925. He was succeeded by Mr. Ole Singstad, who had

been engineer of designs under both Mr. Holland and Mr. Freeman. Under his direction the Holland Tunnel has been completed.

The Holland Tunnel is located in the vicinity of Canal Street, New York City, because that street is a wide east and west thoroughfare giving direct communication across the island of Manhattan. On the east, Canal Street connects with the East River bridges and Brooklyn; on the west, with the Hudson River water front, at approximately the center of down-town traffic over the Hudson ferries.

Its location in Jersey City is at the logical point as nearly opposite Canal Street as is practicable, in order to obtain the shortest tunnel. This point is very near the center of traffic and is advantageously located. It gives direct communication to Jersey City Heights and points beyond by means of the Thirteenth Street viaduct. The water front, with important railroad yards, is easily accessible and adequate communication is afforded with the low-lying parts of Jersey City and Hoboken through streets which parallel the river.

The southerly tube for eastbound traffic extends from Provost and Twelfth Streets, Jersey City, under the Erie Railroad yards, the Hudson River, and Canal Street to Varick Street, New York City. The northerly tube for westbound traffic extends from Broome Street midway between Varick and Hudson Streets in New York City, curving to the west to Spring and Hudson Streets and under Hudson Street and the Hudson River, the Erie, and the Delaware, Lackawanna and Western Railroad yards to Fourteenth Street at Prevost Street, Jersey City.

In planning a public undertaking of the magnitude of the Holland Tunnel, consideration had to be given to many features besides those of actual tunneling. The building of the structure itself was a great engineering problem, but many investigations beyond mere technical design were required.

To secure the best location and arrangement of tunnel roadways, a survey of present and future traffic and the influence of the tunnel on the development of adjacent territory was called for, first of all. Traffic conditions had to be considered from many angles, such as capacity, congestion of the tunnel roadway, adequate approaches, congestion in adjoining streets, width of roadway, and the growth and development of vehicular traffic.

A preliminary forecast of tunnel traffic, based chiefly on the yearly increase in traffic over the Hudson ferries, resulted in an estimate of the number of vehicles that would use the tunnel as follows:

| | Number |
|---|---|
| 1924 (when tunnel was expected to be opened) | 5,610,000 |
| 1935 | 13,800,000 |
| 1937 | 15,700,000 |
| 1943 | 22,300,000 |

Further estimates indicated that a 1-line tunnel would have a capacity about equal to the traffic demand at the opening of the tunnel. A 2-line tunnel would have sufficient capacity to accommodate all traffic up to 1937, while a 3-line tunnel would reach its capacity in 1943.

Obviously it would be unwise to construct a 1-line tunnel whose capacity would be reached as soon as put in operation. As between a 2-line and a 3-line tunnel, it was found that the difference in cost, with interest, would be sufficient to pay for another 2-line tunnel after the first 2-line tunnel had outgrown its capacity. Of greater importance was the consideration that no street or section could accommodate the volume of traffic represented by a 3-line tunnel.

If a 3-line tunnel were built, it could be operated at only 2-line capacity. This would violate two of the main principles governing proper tunnel planning—the distribution of traffic so as to avoid undue congestion, and the investment of capital for construction only as facilities are needed, without the necessity of providing for the distant future. These are two of the most important features in which tunnel construction is held to be superior to bridge construction in crossing wide, navigable rivers.

The cost of a long-span bridge does not vary directly with the span but increases about as the square of the span. On such a bridge no commensurate saving in the cost of construction is obtained by omitting some of its facilities. The tendency in bridge construction, therefore, is to provide facilities greatly in excess of immediate requirements, with a consequent expenditure of capital long before those facilities are needed. Then when there is sufficient traffic to utilize the bridge to full capacity, the resulting congestion in the vicinity of the bridge entrances becomes a serious matter. This is seen in the case of the East River bridges in New York City to-day.

Tunnel construction, on the other hand, is more flexible than bridge construction, because the cost is a direct function of its length, with the volume of excavation increasing as the square of the diameter. Since the cost of excavation represents a large part of the total cost of a tunnel, any increase in the width of roadway can be made only at considerable expense. The proper way to plan a tunnel is to avoid the disadvantages inherent in bridge construction, build only for the present and near future, and construct other tunnels at other locations when the facilities of the first tunnel are outgrown.

Since a 2-line tunnel would have sufficient capacity to accommodate traffic up to 1937, and a 3-line tunnel would create such traffic congestion in the vicinity of its entrances and exits as to preclude its use to capacity; also since the difference in cost between a 2-line and a 3-line tunnel, with interest, would pay for a new 2-line tunnel

when the first was outgrown, the obvious proceeding was to construct a 2-line tunnel and when its capacity is reached, to build another 2-line tunnel at some other location as determined by future traffic conditions. The Holland Tunnel is, therefore, a twin-tube tunnel, providing in each tube for two lines of traffic in each direction.

In planning the entrances and exits of the tunnel, a careful study was made of vehicular traffic, with particular reference to its movement at street intersections and through the tunnel. It was recognized that wherever traffic intersects, its continuity is broken. Instead of moving in a steady stream, it breaks into a series of waves as it is held up and released at intersections. This interruption in the stream of traffic at street intersections so limits the capacity of a street that its real capacity as determined by its width is never reached.

A tunnel differs from a street in that the only interruptions by cross traffic are at the entrances and exits. Consequently these points are of vital importance, affecting as they do the ultimate capacity of the tunnel. Unless the entrances and exits insure continuity of traffic during the period of maximum demand, the capacity of the tunnel roadway can never be reached.

Accordingly, the entrances and exits of the Holland Tunnel are widely separated. In New York City, one is to the north and the other to the south of the Canal Street through traffic; in addition they are located so as to be served by two main north and south avenues. Tunnel traffic is thus given the best possible facility for free movement while at the same time the greatest separation is secured at a reasonable cost. In accord with this same principle the entrance and exit at the Jersey City end are located in separate streets adjacent to the railroad yards east of the north and south traffic streets connecting Jersey City with Hoboken.

This separation of the tunnel entrance and exit traffic is considered to be a factor of the greatest importance in relieving congestion in the vicinity of the tunnel. This was particularly necessary in New York City, with its large and rapidly increasing volume of traffic. It was also called for in Jersey City, where there were no wide thoroughfares in the vicinity of the tunnel.

In addition, property was taken to provide broad plazas at entrances and exits. The entrance plazas serve to accommodate the waves of traffic as they approach the tunnel and converge in the portal roadway into continuous lines of vehicles through the tunnel. Similarly wide exit plazas insure the free and uninterrupted movement of traffic away from the tunnel. Through the separation of entrance from exit, and the use of adequate plazas, the tunnel traffic can be distributed over a large number of streets.

In considering the requirements for the width of the roadways and the clear headroom needed, measurements were taken of vehicles crossing the Hudson on the ferries between New York and New Jersey. It was found that their height varied from 6 feet 6 inches for passenger cars to a maximum of 13 feet for large loaded trucks, but that the number exceeding 12 feet in height was only 1 per cent. The width of motor vehicles varied from 6 feet for passenger cars and light trucks to a maximum of 10 feet 6 inches for army transport trucks. In the case of 3-horse teams, the outside dimension of the three horses abreast was 9 feet, but the number of vehicles exceeding 8 feet in width was only 3½ per cent.

In determining the amount of clear headroom required, it was necessary to consider the matter of providing sufficient area in the tunnel roadway. Any increase in clear headroom, without increasing the size of the tunnel, could be made only at the expense of the available ventilating duct area. Any reduction in this area would increase the power required for ventilation and add to the cost of operating the tunnel.

Given a maximum height of 12 feet 2 inches and a maximum width of 8 feet, a clear headroom of 13 feet 6 inches seemed adequate to allow even for jacking up vehicles in case of breakdown, and this was decided upon.

Normal operating conditions in a tunnel accommodating two lines of vehicles in the same direction on one roadway obtain when there is a slow line of heavy trucks 8 feet wide abreast of a fast line of light trucks and passenger cars 6 feet wide. It is, however, necessary to provide for such a contingency as when a vehicle of maximum width has to pass another of the same width that has stalled. The roadway has to be sufficiently wide to permit the passage abreast of two vehicles of maximum width.

It was believed that in the slow line, operating at a speed varying from 3 to 6 miles per hour, a clearance of not less than 6 inches between the outside of the tire and the curb should be provided. In the fast line, due to the greater speed, this clearance should not be less than 1 foot. It was also considered that for safe and convenient operation a clearance between moving vehicles of 2 feet 9 inches should be allowed. These considerations led to the adoption of a width of roadway of 20 feet, with, in addition, a sidewalk 2 feet wide in each tunnel. This sidewalk is set back from the curb line a distance of 6 inches and is located at an elevation of 26 inches above the roadway.

This roadway is paved with granite blocks laid in the usual sand cement cushion layer, about 1 inch thick, with the joints filled with hot asphalt mixed with heated sand. By means of squeegees, a thin coating, sprinkled with sand, is left upon the surface, resulting in a

smooth, resilient, and long-wearing surface that will help to deaden the sounds due to traffic, and be more quickly repaired than concrete.

Each side of the roadway is lined with a granite curb, the roadway having a transverse slope from one side to the other, with a depressed concrete gutter behind the curbstone on the low side with side inlet openings at frequent intervals. The drain connects with a sump at the low point of the tunnel, from which a discharge pipe is carried under the roadway of each tunnel to the New York River shaft. Intercepting sumps with pumping equipment are provided in all the river and land shafts.

The tunnel is lighted by electric lamps located in the side walls of the tunnel immediately below the ceiling slabs. A continuous water main is provided throughout the entire length of each tube, with hose connections for fire protection and flushing at frequent intervals.

The walls are lined with white tile, care being taken to eliminate all tile containing blue, green, or red tints, upon advice of a "color psychologist," on account of its "depressing effects." The color of the borders is a light orange. The ceiling is painted white.

The tunnel, with its twin tubes, 29 feet 6 inches in diameter, is the largest subaqueous tunnel in America, exceeding by 6 feet 6 inches the Pennsylvania Railroad tubes. On the New Jersey side, the diameter of one of the tubes is increased to 30 feet 4 inches to meet ventilation requirements. This exceeds by 4 inches the diameter of the Rotherhithe Tunnel under the river Thames, London, England, which has been the largest subaqueous tunnel in the world.

The shield method of construction was adopted for the Holland Tunnel after careful consideration of other schemes, notably the trench method. By the trench method, the work is conducted from a plant floating in the river, and the tunnel is constructed either under a protecting roof or floated into position and sunk in sections in a dredged trench. The longest subaqueous tunnel built by this method is the Detroit River tunnel of the Michigan Central Railroad.

It was recognized that in the excavation of a trench under the Hudson River, there would be an unavoidable interference with a great volume of river traffic. Fifteen hundred boats cross the line of the tunnel daily. Such congested river conditions would make every dredge or other machine working in the tunnel an obstruction to traffic. Collisions would be frequent, increasing the time and cost of the work, with danger both to shipping and to the equipment of construction. Storms, fog, and ice would cause a discontinuance of surface work for at least two months of each year. At the New York end, a large mass of ledge rock, involving blasting and removal at great depth, would be a serious obstacle to open-trench excavation under water.

Since there was a real hazard involved in carrying on operations from a plant anchored in midstream, the shield method was clearly called for. In addition, silt conditions in the Hudson River were regarded as extremely favorable to this method. In a trench tunnel, soft material greatly increases the volume of excavation, while in the case of a shield tunnel this material is most easily excavated. If the silt is not shoved aside by the shields, it is easily disposed of through the tunnel. The shield may be closed with the exception of certain openings through which the material is squeezed into the tunnel as the shield advances.

The first contract provided for the sinking of two land shafts, one at Washington and Canal Streets and the other at Washington and Spring Streets, New York City. They were sunk by the compressed-air method.

The double steel walls of the caissons were filled with concrete as the caissons were sunk. This added to their weight when sinking weight was needed, and at the same time completed the structure of the walls. In addition to this concrete, weight for sinking was obtained by storing the excavated material from the working chamber on the roof of the chamber as the caisson went down. This necessitated handling the material a second time, but gave the desired weight and permitted the lowering of the caisson without greatly reducing the air pressure in the working chamber, thereby preventing loss of ground.

Upon the removal of the compressed air, the bottom seals of the caissons proved to be water-tight. The shafts were now ready for the building of the shields preparatory to the beginning of shield tunneling. Temporary bulkheads were provided in the west side walls to permit the passage of the shields, and in the east side walls to connect with the approach section which was to be constructed by excavation from the surface.

This work was followed by placing under contract the entire under-river portion of the tunnel. Power plants had to be constructed to produce low-pressure air for caissons and tunnel, high-pressure air for the operation of grouting machines, air drills, and hoisting engines used below the surface, and hydraulic pressure for operating the jacks used in driving the shield and for operating the erector arm for building the tunnel lining.

Overhead gantries and dumping platforms for the receipt and disposal of materials and buildings for housing the workmen had to be provided. Pipes, through which compressed air would be supplied to the tunnel headings, had to be laid to the shafts. On the New Jersey side this involved laying low-pressure lines as large as 16 inches in diameter, high-pressure lines, hydraulic lines, water

lines, electric cables, and telephone cables. Every facility had to be provided, even an independent telephone system connecting all parts of the work with the public telephone system.

Canal Street Park was made available as a site for the air-compressing plant and engineer's field office. Pier 35 and adjacent slips were used for the storage of materials and for the disposal of excavated matter from the tunnel heading. Overhead gantries connecting the shafts with the pier permitted traffic to the water front in connection with the tunnel to pass above the city streets.

The first shield was erected in the Canal Street shaft. On October 26, 1922, compressed air was introduced into the shield chamber, and tunneling was begun. Each shield was 30 feet 2 inches in outside diameter, 16 feet 4 inches long, and the upper half was equipped with a hood projecting 2 feet 6 inches ahead of the shield proper. Five vertical and three horizontal walls divided the shield into 13 compartments, through which the ground in front was excavated. It was equipped with thirty 10-inch jacks, having a combined thrust of 6,000 tons. A hydraulic erector was used to build the tunnel segments into a complete ring. The weight of the shield, with all equipment, was about 400 tons.

The tunnel lining is composed of rings 2 feet 6 inches wide, consisting of 14 segments, each approximately 6 feet long, with a key 1 foot long, bolted together. Inside the lining is an inner lining of concrete 19 inches thick. As the shield advanced and the lining was erected behind it, the space due to the difference in the diameter of the shield and the rings forming the lining was filled by forcing a grout of cement and sand in equal parts into the void under high air pressure. For this purpose each segment was provided with a grout hole fitted with a screw plug. The lining was made water-tight by placing hemp grommets soaked in red lead around the bolts, and by caulking lead wire into grooves between the segments.

Shield driving requires extreme care and exactitude to keep to line and grade. The position of the shield fixes the location of the tunnel, and no correction can be made afterward. It is absolutely essential that the slightest deviation of the shield from its theoretically correct position be known at once, so that measures may be taken to remedy the error during the next shove. The shield is guided by the operation of the jacks distributed around its circumference, omitting the use of those jacks in the direction toward which the shield is to move.

Every precaution was taken to provide for the safety of the workmen in the compressed-air chambers. A high emergency gangway in the upper part of the tunnel led from the shield to the locks, for escape in case of a blowout. Safety screens were installed to trap the

inrushing water. Fire lines were installed in the compressed-air chambers. Fire is a real danger in compressed-air work on account of the increased amount of oxygen present. As an indication of the fire hazard, a candle, if still glowing when extinguished, will again burst into flame.

The starting of the shields out of the caissons at the New York land shafts was difficult because of the large diameter of the shields and the shallow cover overhead. The material at this point was granular, consisting largely of fine sand, which if undisturbed, held air fairly well. As the shields were under the city streets, it was impossible to increase the cover overhead. To avoid blow-outs at the face with the consequent inrush of water, it was necessary to regulate the air pressure carefully and to protect the face during each successive step in excavating.

As a preliminary step to shoving the shields out of the caissons, the circular steel bulkheads in the caissons were burned out in front of the shields. The work was done by removing the steel in horizontal layers, each layer carefully protected as the steel was removed to avoid exposing a great area of the face to air leakage, especially when the air pressure sufficient to dry out the bottom would be heavy enough to cause a blow-out at the top.

Removal of the steel bulkhead was started, with the steel above intact and with air pressure sufficient to dry out the bottom. After the lower third of the steel bulkhead had been removed, a wooden bulkhead was built in front of the shield, and the space between this bulkhead and the ground ahead was packed with clay. The air pressure was then reduced until it balanced the water pressure at the top of the shield, and work was begun at the top, removing the top plates and proceeding downward.

As these plates were removed, breast boards packed front and back with clay were inserted to cover the exposed excavation. This work proceeded down to the point where the bottom plates had previously been removed, while at the same time the air pressure was raised step by step to balance the water pressure. The shield was then advanced against the wooden bulkhead at the bottom, compressing the clay which was removed as the shield advanced, with the jacks reacting against the cast-iron tunnel lining temporarily erected in the shaft.

In order to prevent the leakage of air around the hood of the shield, an annular pocket was excavated ahead of the hood the full length of a shove, and this pocket was packed with clay. This served a double purpose: First, the hood, as the shield advanced, cut into this clay and made a thorough seal in front against air leakage; and second, by exploring the full length of the shove, assurance was had that the shield would not pick up and drag timbers in front of it, leaving open channels behind them through which air could readily

escape. The necessity of taking this precaution is evident when it is considered that at this point there were but 14 feet of cover above the shield to the street surface, and only 8 feet from the top of the shield to the under side of an old brick sewer, which would readily allow the air to escape from the tunnel heading.

As the tail of the shield left the caisson, grouting was at once started to fill the annular space which the shield left outside the tunnel lining. Every effort was made to keep this space fully grouted, even to the extent of stopping the shield in the middle of a shove to keep the grout up with the shield.

The method just described was later modified so that in the bottom quarter of the shield, instead of packing ahead with clay, a fixed wooden bulkhead was built in the shield, and the shield was advanced into the fine wet sand with this bulkhead in place. This compressed the earth, driving out the water, so that the material was firm and could be excavated during the shove over the top of the bulkhead, or through small openings cut in the bulkhead itself. This prevented a free run of wet material into the bottom which is the ordinary method of tunneling under the river.

The grouting previously described was continued, and not only prevented an abnormal escape of air at the tail of the shield, but also prevented settlement of the streets and adjacent buildings. The buildings at the corner of West and Spring Streets settled slightly, but at no time were they in need of shoring, nor were the occupants disturbed at any period of the tunnel work. This was the situation also with the New York Central tracks under which the Canal Street tunnel was driven. The grouting was carried on so effectively that it filled some of the old sewers in the vicinity which later had to be cleaned out.

The Canal Street shield passed very close to a cofferdam around an excavation for a sewage treatment plant, and it was evident from the first that great care must be exercised in driving the tunnel past this location. At the nearest point the shield was within 5 feet of the steel sheeting of the cofferdam, with the bottom of the sheeting at about the springing line of tunnel. On November 30, when the shield was about 40 feet away, it was noticed that sand and water were being forced through the sheeting into the cofferdam by the air pressure from the tunnel heading. In about 2 hours approximately 150 cubic yards of earth had been blown into the excavation from behind the sheeting, and it was plain that not only was the cofferdam in danger, but the continuation of tunneling operations would be hazardous because the cavities left in the ground provided open channels for the leakage of air, which might have resulted in a tunnel blow-out. It was decided that tunneling operations should be temporarily suspended, that the steel sheeting of the cofferdam

should be left in place permanently, and the concrete walls of the permanent structure placed immediately, being increased in thickness to enable them to withstand the pressure from tunneling operations.

Preparatory to tunneling under the river bulkhead, clay and other material to prevent the escape of the compressed air from the tunnel were deposited in the slip between the piers and on the landward side of the river bulkhead to fill such voids as might remain around the tops of the piles supporting the timber platform of the bulkhead construction. Not only were the voids around the piles filled, but the soft mud in the slip was displaced by the heavier clay, a firmer material and better adapted to resist air leakage.

In this section great care was taken in excavating ahead of the hood to be sure that all piles within the area of the tunnel section were cut off before coming in contact with the shields. This was done to avoid pushing the piles through the ground and leaving back of them an open channel for air to escape. These piles extended down to the springing line of the tunnel excavation, and as many as 30 had to be cut off at one time in advancing the shield the length of one ring. In this manner both shields passed under the river bulkhead without accident.

The tunnels then entered the Hudson River silt. The front of the shield was completely bulkheaded. Some of the lower pockets in the shield were opened to allow a part of the material to enter the tunnel as the shield was advanced. The balance of the material in excavation was displaced bodily. At once it was noticed that there was a tendency of the tunnel lining to rise behind the shield. This rising always accompanied the movement of the shield; whenever the shield was stopped the rising ceased. The difficult feature at this point was that the shield was so heavy that it settled while the cast-iron tunnel lining behind the shield rose, so that the shield at all times was below grade while the tunnel lining a short distance back was above grade.

The bulkheads in the shield were moved forward to reduce weight by lessening the amount of muck in the shield. This aided somewhat in keeping the shield from settling and then more material could be taken in through the shield. This procedure lessened the pressure on the tunnel behind and reduced its tendency to rise. As the contract required that a second tunnel bulkhead should be constructed in this vicinity, the south shield was stopped after passing through 218 feet of silt and the bulkhead was built. This bulkhead, which is typical of all the bulkheads, is a concrete wall 10 feet thick, equipped with the usual muck, man and emergency locks, and adds temporarily considerable weight to the tunnel.

With this additional weight, the rising of the tunnel was somewhat checked and after tunneling a distance of 121 feet farther

in the silt the shield entered at the bottom of the sand layer which overlies the rock, and thereupon all rising of the completed tunnel during shield driving ceased. In the north tunnel, which was driven through the same material after the south tunnel was built, a larger amount of material was taken in through the shield at the start, and while there was some rising of this tunnel behind the shield, it was very much less than in the south tunnel. In neither tunnel was the movement sufficient to endanger the structure.

The excavation in the part-earth and part-rock section just east of the New York river shaft caisson was carried on by driving a short bottom heading in advance of the shield, in which was placed a concrete cradle with steel rails embedded in it upon which the shield slid. After placing the cradle the rock was blasted out for one or two advances of the shield and then the soft material on top was carefully excavated and supported by poling and breast boards.

The New York river ventilating shaft caisson was sunk by the compressed air method in the river near the New York pierhead line. It was built on launching ways, then launched and drydocked. After concrete had been placed in the pockets surrounding the working chamber, additional steel was erected, carrying it to a height of 55 feet.

A platform supported on piles had been built on three sides of the site (the south side being open ready to receive the caisson), and the caisson was towed to its position on the work. The caisson at that time weighed approximately 1,650 tons. Upon arrival, additional steel was erected and concrete was placed in the walls, the caisson sinking as the additional weight was placed. Care was taken to keep the center of gravity as low as possible to maintain the necessary stability. When it had reached a depth of 35 feet, the cutting edge encountered the river bottom, into which it settled at each low tide, and weight was added with sufficient rapidity to overcome the tendency to float on the subsequent rising tide.

No excavation was carried on in the working chamber until the cutting edge had penetrated about 9 feet into the mud, as the weight of the caisson displaced the material up to this point. Compressed air was then introduced into the working chamber and the usual shaft mucking operations started. At a depth of 69 feet below mean high water, rock was encountered. This was taken out in lifts about 6 feet deep and the caisson was lowered by successive drops until it reached its final position.

The upper half of the outside of the caisson, or the part which is exposed to open water, was covered with water-proofing, which in turn was covered with an 18-inch layer of protection concrete. An additional protection is afforded in the upper portion by a granite facing where the shaft is exposed to tidal action.

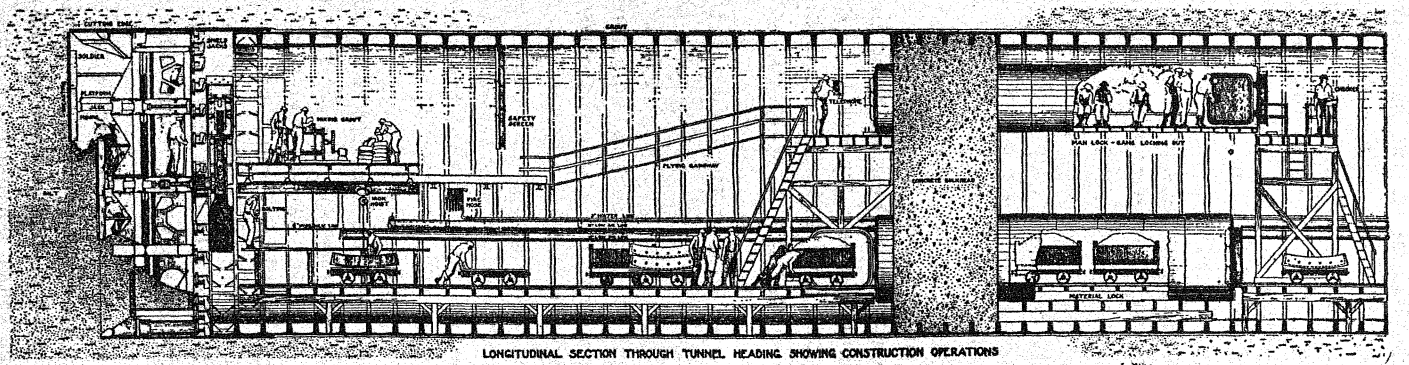



FIGURE 2.—Longitudinal section through tunnel heading showing construction operations. Below: Rear of shield showing erection of iron and mucking in process; view from rear of shield with bolting and grouting in process; exterior view of concrete bulkhead showing air locks

After the caisson was sealed to the rock and waterproof, the east and west shield bulkheads in both the north and south tunnel chambers were burned out and both shields were driven through the caisson. A timber and concrete cradle of sufficient strength to carry the shield was erected in each chamber and the shield jacked across. After the shields had progressed a sufficient distance west of the river shaft to permit tunnel bulkheads, these were built in each tunnel and placed in operation. After this, tunneling operations were carried on from the river shaft, releasing the tunnels between the land and river shafts for the placing of concrete lining.

The caissons for the north and south land shafts on the New Jersey side were assembled and sinking started in the fall of 1922. After the caissons had passed through the cinder fill of the railroad yard, a timber crib filled with riprap was encountered which made excavation extremely difficult. The timbers had to be sawed or chopped into short lengths and some of the rock broken up.

The distance between the tubes on the New Jersey side required the sinking of two separate river ventilating shafts. This presented a problem due to depth of the bedrock, 250 feet as compared with 70 feet on the New York side. It was considered that the silt which overlies the bedrock would not afford a satisfactory support.

Accordingly, it was decided to support the shafts by means of steel casings 24 inches in diameter, filled with reinforced concrete, extending from the bottom of the shafts to ledge rock. They were made in lengths of 20 feet, threaded at both ends for couplings. Three lengths were connected and one end lowered into the silt. The silt inside the pipe was then loosened by churning with a 2,000-pound bit, and the mud and water bailed out. Excavation was continued in this manner to a depth of approximately 20 feet below the bottom of the pipe. The material was firm enough to prevent caving into the hold. Another section of pipe was then added and the entire section driven into the hole previously excavated.

The north tunnel shield east and the south tunnel shield west were built first and started out from their respective caissons. After the south tunnel shield west had progressed a sufficient distance to erect a tunnel bulkhead, the face of the shield was bulkheaded and the roof was removed from the south caisson and the south tunnel shield east was erected. As soon as this shield was ready, the roof was replaced on the caisson and the shield was started eastward, so that at the close of 1923 two shields were tunneling eastward, and one westward.

The method followed in starting these shields out of the shafts was similar to that already described for the New York shields, except that here it was not so difficult as there was adequate cover overhead. After the roof of the working chamber had been replaced, the

girders in the side of the caisson, through which the shield was to be advanced, were burned out, after which the plates were removed from the invert to the springing line. The lower pockets of the shield were then bulkheaded and the space between the pockets and and the exposed face was filled with clay. After this, the remaining plates were removed, proceeding upward from the springing line. A semicircular annular ring was cleared for the hood and packed with clay into which the hood was forced when the shield was advanced.

The material at the face consisted of timber and riprap down to the springing line, similar to the material encountered in shaft sinking, making excavation very difficult. The stones in the crib varied from 1-man stones to those three-quarters of a yard in size. The voids between the stones were filled with soft black mud, which did not offer sufficient resistance to prevent the escape of air, necessitating the mudding up of the entire face with clay. As the excavation was carried forward, the escape of air through the heading of the north tunnel at times taxed the full capacity of the power house, 40,000 cubic feet of free air per minute.

On June 10, 1923, a small blow occurred at the face of the shield and it became necessary to drop the air pressure sufficiently to allow the water to flow into the tunnel before the blow could be stopped. The progress through the riprap was very slow, as extreme measures had to be taken to avoid blow-outs. After the shield had passed through the old timber and riprap crib, the river bulkhead was encountered which did not offer any unusual difficulties.

Before tunneling through similar material in the south tunnel east 5,500 bags of 1:1 Portland cement grout were ejected through the east shield bulkhead of the south caisson and six pipes were sunk from the surface east of the caisson through which 140 bags of 1:1 Portland cement grout were placed. This grout displaced much of the soft mud and filled the voids in the riprap and greatly facilitated the driving of the shield so that very little air escaped through this material after it had been consolidated by grouting.

After about 60 rings were erected in each tunnel, the shields were stopped to build tunnel bulkheads and to install cages at the shafts and then tunneling was resumed. Immediately east of the river bulkhead soft mud, considerably lighter than Hudson River silt, was encountered in the upper part of the excavation. In this material the tunnel began to rise directly behind the shield and also to move northward.

To hold the shield and the tunnel to the proper grade, it was necessary to take in a certain amount of material through the shield. Accordingly, the shield was advanced with the top pockets bulkheaded and a large percentage of the excavation was permitted to enter the tunnel through openings in the lower part of the shield.

This material had to be entirely removed after each shove before the erection of the cast-iron lining could proceed and slowed down progress. In addition it was desired to retain this material in the tunnel directly behind the shield so as to increase the weight of the tunnel and reduce the tendency to rise.

To meet this situation a different method of tunneling was adopted. The work was stopped and a steel bulkhead semicircular in shape and fitting into the lower part of the tunnel was built to trail about 10 feet behind the shield, and four pockets of the shield immediately above the springing line were equipped with hydraulically operated doors. When the shield advanced, these doors were opened varying amounts, depending upon conditions, to allow the material to flow through the shield into chutes which cropped the silt back of the trailing bulkhead. This method of tunneling permitted both the shield and the tunnel to be kept on grade.

River-shaft caissons were built, launched, floated into position, and sunk, as on the New York side.

On October 22, 1924, shield driving was suspended in the north tunnel from the New York side and a bottom heading or junction drift was started to meet a corresponding drift from the New Jersey heading. On October 29, the rock barrier remaining between these headings was blasted away. After this all tunneling operations were conducted from the New York side, as the junction was much nearer the New York shaft. The south tunnel headings were joined on December 7, 1924. Work on the New York side was suspended and the New Jersey shield driven to meet the New York shield.

In July, 1924, the placing of the concrete lining forming the roadway and air ducts was started on the New York side in the north and south tunnels between the land and river shafts. The concrete invert was first placed in both tunnels from the land shafts to the river shafts. The remaining concrete was then poured in nine operations. Five types of collapsible steel forms in 60-foot sections, afterward increased to 75 feet, supported and moved by carriages resting on previously placed concrete, were used.

The approach tunnels from the land shafts to the open approaches at Dominick and Hudson Streets, New York City, and at Provost Street, Jersey City, were built by the cut and cover method as usually employed in subway construction.

A visitor to the Holland Tunnel in 1924 has written the following graphic and interesting story of the shield method of construction. The invitation to inspect the tunnel read, "Wear old clothes and bring your galoshes."

Such was the admonition of our host on a warm September evening in 1924. But knowing our host, we complied without ado other than a casual lifting of the eyebrows. Ten o'clock that evening found four of us being piloted toward Canal Street and the administration building of the Vehicular Tunnel.

Chief Engineer Holland himself greeted us, and began an introduction to this vast engineering project with maps, diagrams, and more maps and diagrams, till red lines showing tunnels, and blue lines showing traffic lanes, and green lines showing river bed swam before our gaze. We nodded very knowingly, mumbled pleasantly that exquisite shades had been chosen for the various lines, and moved on to the doctor's office.

Here we were introduced to the necessary procedure before going into compressed-air chambers. Ears, heart, and blood pressure were examined. As we were found physically fit, we were passed on to the wardrobe, where we were presented with an assortment of khaki cover-alls and left to our own discretion as to choice.

The first twinge of squeamishness about cleanliness was quickly dispelled by the romatic second thought that the very men who were performing this miracle under the river had worn these self-same garments. Then followed a scramble for the most bespattered on the theory that such muck was a mark of courage in dashing into subaqueous passages. Size was completely disregarded. Never in all the stages of dressing up to set forth for adventure in my childhood days had I enjoyed more of a thrill as so arrayed we followed our guides to the tunnel entrance.

Once inside we were amazed to find what a simple form such a complex sounding work could assume. The tubes are made of cast-iron segments bolted together. Fourteen of these sections are required to make a complete ring. Each section weighs 1½ tons and is held in place by huge bolts weighing 10 pounds.

"Oh's" and "Ah's" were vented as we continued our way to see the actual excavating. We passed groups of men sitting about talking, laughing, and playing cards, awaiting their shifts. Work was never stopped 24 hours a day, 7 days a week. (With an investment of $42,000,000, it was imperative that no time be lost.) We met car after car of excavated material on its way down the temporary tracks to the entrance and out to be dumped.

At last we arrived at the great concrete bulkhead that sealed the compressed-air section, separating it from the completed portion of the tunnel.

The bulkhead contained four air chambers or locks. Two large compartments at the bottom of the bulkhead were equipped with tracks for bringing supplies to the workers and for removing the excavated material. Two smaller chambers were provided in the upper section for the workmen who on entering and leaving the tunnel must be gradually brought from one pressure to another.

We entered one of these (only one was used normally, the other reserved for emergencies) and saw the iron door clanged to and fastened. Then followed lessons in equalizing the pressure inside and outside the head by holding the nose and "snorting"—very much as one does when trying to expel water from the nose after diving. The danger of the "caving in" of one's eardrums was stressed, and we were warned to hold up our hand the moment the pressure became too severe. This was the only way to attract the attention of the man who turned on the compressed air, as the noise made even shouting inaudible.

We sat wild-eyed, expecting the hideous monster to leap upon us any minute. The bark was worse than the bite. Twice we raised our hand and the pressure was turned off until the pressure in our ears was relieved. When the 29-pound mark was reached the door leading into the high-pressure section was opened, and there we were in the very midst of the digging.

Once accustomed to the pressure, it was not noticeable, and we began a siege of questions about the actual excavating.

This work was done under a shield, or movable head, slightly larger than the external diameter of the tunnel. The shield was forced forward 2½ feet

at a time, the width of a section, by means of 30 hydraulic jacks supported against the end of the tunnel already built. Several of the jacks were then removed and a segment was hoisted into place by a tremendous erector arm till a complete ring had been added, and then the shield was forced ahead again. Doors in the lower part of the shield allowed about 30 per cent of the displaced compressed silt to enter the tunnel on each shove.

We stood watching the big burly men as they shoveled the débris into the cars that carried it out through the lower air chambers. Not particularly envious of them at such hard labor, we listened only half-heartedly to our guide until he remarked that the automobiles we had seen parked at the entrance belonged to these very "sand-hogs"; that they made high wages and worked short hours. There are laws forbidding their working in compressed air for more than two hours at a time for health reasons. Law likewise requires the company employing the men to furnish hot showers and hot coffee for them when they come out.

From the digging we turned to watch the erector; two men tugging at a mammoth wrench tightening the bolts; the grouting machine as it forced its mixture with pressure beyond the segments to form a concrete shell for the whole tube; and then to discuss the miracle that prevented the Hudson itself from pouring in on us in one deluge. There we stood with only a few feet of sand and gravel between us and the river.

"Chief" Holland and the rest of the engineers chatted with us as casually as if it were a game of tiddle-de-winks they were explaining, instead of an achievement that even seeing denied believing. We picked up bits of rock for souvenirs and continued gasping when one of our hosts turned questioner. He asked if we could whistle.

Assuring him that whistling did not stump the modern girl, we inquired his preference as to a tune. He consulted the other men, and after much deliberation proposed to give us a big party on the condition that we whistle "Yankee Doodle"—all five verses. With one accord lips were puckered and cheeks distended. Our chagrin was only equaled by the laughter of our tormentors as we puffed and blew in vain. The party was given for effort and not for the results obtained against 29 pounds of pressure.

In quitting the compressed air it was necessary to put on fleece-lined coats to prevent catching cold. We retraced our steps through the man lock, where the pressure was reduced gradually back through the tube, and insisted on the law requirement of hot coffee on signing off.

The problem of ventilation of the Holland Tunnel was unlike any heretofore solved, both in character and magnitude. The only existing vehicular tunnels even approximately comparable to the Holland Tunnel are the Blackwall and Rotherhithe Tunnels under the Thames at London.

The Blackwall, opened for traffic in 1897, has an under-river length of 1,221 feet between shafts. It consists of a single tube 27 feet in diameter with a roadway accommodating one line of traffic in each direction and two sidewalks. Traffic counts in 1920 showed that the maximum number of motor vehicles using the tunnel was less than 100 per hour.

The Rotherhithe is 30 feet in diameter, similar to the Blackwall in traffic facilities, with an under-river length between shafts of 1,570

feet. Both of these tunnels are ventilated by the natural movement of air through the shafts and portals. The Holland Tunnel, with a total length of 9,250 feet, an under-river length of 5,480 feet, and a capacity of 1,900 vehicles per hour in each direction, or 46,000 per day, obviously required something more than natural ventilation. To this end the ventilation of the tunnel was studied under three heads:

1. The amount and composition of exhaust gases from motor vehicles.
2. The dilution necessary to render the exhaust gases harmless.
3. The method and equipment necessary for adequate ventilation.

The impurities in the atmosphere of a tunnel used by motor vehicles are the product of the combustion of gasoline. If complete combustion occurred, the carbon content in the gasoline would be in the form of carbon dioxide, which can be tolerated in considerable quantity without injurious effects. In a gasoline engine, however, complete combustion seldom, if ever, takes place. The exhaust gases contain varying amounts of carbon monoxide, depending on such variable factors as the quality of the gasoline, conditions of carburetion, etc.

Carbon monoxide is a highly poisonous gas, injurious to health in minute quantities if breathed for a long time, and if present in large quantities is injurious even when breathed for a short time. Ventilation requirements are determined by the quantity of this gas in exhaust gases. If sufficient fresh air is supplied to reduce this gas to a safe percentage, other gases and impurities, such as carbon dioxide, methane, and smoke, will also be diluted sufficiently. The first consideration, therefore, was to determine the amount of carbon monoxide that would be liberated in the tunnel.

Investigations were carried out at the Bureau of Mines experiment station at Pittsburgh. The schedule called for the testing of passenger cars and trucks of various makes and capacities. The tests were made with cars loaded and light, standing with engine racing and idling, accelerating from rest on level grade and on maximum grade, running at 3, 6, 10, and 15 miles per hour on level and up and down a grade of 3½ per cent, corresponding to the maximum tunnel grade. A total of 101 cars were tested. Gas samples were taken directly from the exhaust pipe throughout the entire duration of the test.

In general, the results showed that the exhaust gases contained about 6.8 per cent carbon monoxide and 8.4 per cent carbon dioxide, developing only 67 per cent of the heat value of the gasoline. About one-third of the gasoline fuel was wasted through incomplete combustion.

Experiments to determine the proper dilution to render the exhaust gases harmless were conducted at the Bureau of Mines experiment station at Yale. They were performed in a gas-tight

chamber of 226 cubic feet capacity. Members of the staff spent periods of one hour in air containing amounts of carbon monoxide varying from 2 to 10 parts in 10,000. In addition, tests were performed in a chamber of 12,000 cubic feet with an automobile engine exhausting into the chamber. The duration of all tests was one hour, whereas the length of time required to travel through the tunnel at a speed of only 3 miles per hour is but 31 minutes.

The results of the test showed that when an automobile engine is running properly the exhaust contains no substance that is injurious to any appreciable extent except carbon monoxide. Gasoline engines with cylinders missing, or when cold, over-supplied with oil or gasosline, or smoking from any cause, may throw off disagreeable vapors irritating to the eyes and nauseating to some persons.

The physiological effects of carbon monoxide are wholly due to the union of this gas with the hemoglobin of the blood. To the extent that hemoglobin is combined with carbon monoxide, it is by that amount incapable of transporting oxygen to the body. This combination of carbon monoxide with the hemoglobin is reversible, so that when a person returns to fresh air the carbon monoxide is gradually eliminated.

Of all physical signs and tests of carbon monoxide poisoning, headache proved the most definite and reliable. Concentration of gas too weak or periods of exposure too short to induce a headache are to be considered harmless. No one had this symptom to an appreciable degree after a period of one hour in the chamber with four parts of carbon monoxide. With six parts the effect was usually very slight, while with eight parts there was decided discomfort for some hours.

Hence a uniform concentration of four parts carbon monoxide in 10,000 of air is designed to afford not only complete safety, but also comfort and freedom from disagreeable effects.

By the longitudinal method of ventilation, the entire tunnel would be utilized as a duct for conveying air through the tunnel. Sufficient air would be supplied through blower fans near one portal and would enter the tunnel through a nozzle or nozzles at a velocity sufficient to force it through its entire length.

If in a 29-foot tunnel the air were introduced into the north tube near one portal through a nozzle having a cross-sectional area of 74 square feet, and were exhausted through the opposite portal, the air would have a nozzle velocity of about 282 miles per hour. This would produce a velocity of 72 miles per hour at points where the roadway was occupied by a pleasure car and a truck abreast, or a velocity of 51 miles per hour where there were no vehicles. Such air velocities would be prohibitive in a vehicular tunnel, and the power required to handle the air would be excessive.

In the distributive method of ventilation adopted for the Holland Tunnel, the air is introduced into and exhausted from the tunnel through a number of openings at frequent intervals leading from the tunnel roadway. By this method fresh air is supplied at all points throughout the tunnel. The air at any point can be controlled. There is no discomfort or danger from high-velocity air currents. The ventilation is not affected by traffic or the direction of the wind. Exhaust gases are quickly diluted and removed.

The space above and below the tunnel roadway is ideally suitable for air ducts. Fresh air, supplied by blower fans at the shafts, is discharged from the main duct under the roadway through adjustable openings into continuous expansion chambers on each side, thence

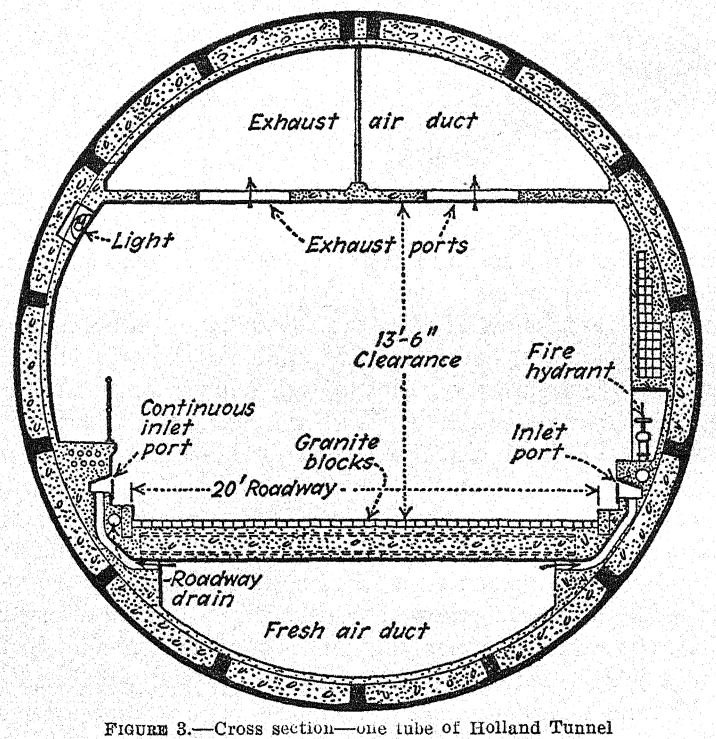



FIGURE 3.—Cross section—one tube of Holland Tunnel

through a continuous slot into the roadway. The air remains in the tunnel an average of 1½ minutes as it slowly ascends to the ceiling.

Exhaust fans located in the same buildings with the blower fans draw the vitiated air through ports in the ceiling and thence through the upper duct above the roadway, delivering it through stacks to the outer atmosphere.

Experiments to determine the coefficient of friction for flow of air in concrete ducts, to verify formulae used in computing the power required for moving air through a duct from which air is taken off

at intervals, and to determine the power losses in bends or elbows in concrete air ducts were conducted at the engineering experiment station at the University of Illinois.

A concrete model, the linear dimensions of which were one-half those of the lower duct of the tunnel, and 300 feet in length was used for direct tests. Outlets with adjustable shutters to control the flow of air were provided at uniform intervals on each side. Measurements of air velocity and static pressure were made at three locations in the duct, one 5 feet from each end and one midway. Tests were run with all side ports closed and port pockets open at various intervals, and with air velocities ranging from 1,000 feet to 6,000 feet per minute. A total of 186 blowing tests and 17 exhausting tests were run from which to determine the coefficient of friction.

On a full-size model of the expansion chamber proposed for the tunnel, tests were made to determine the proper shape of the chamber and the shape and size of the slot which would give a direction of air flow high enough not to raise dust from the roadway and low enough not to short circuit the fresh air to the inlets into the vitiated air duct over the roadway. These experiments also gave the minimum static pressure required to discharge the requisite quantities of air through the slots at different locations in the tunnel. A total of 112 tests were made on various shapes of expansion chambers and various widths of slot under the several conditions to be met in the tunnel.

Experiments on elbows were made in two parts: On galvanized iron single and compound elbows constructed to one-tenth the interior dimensions of the elbows to be used in the tunnel, and on concrete compound elbows to one-half the interior dimensions of those planned for the tunnel ducts.

To verify under tunnel conditions the amount of carbon monoxide produced by automobiles and the physiological effect of exhaust gases, an experimental tunnel was constructed in the workings of a coal mine at Bruceton, Pa. It was located about 1,000 feet from the entrance to the mine and about 135 feet from the surface. The tunnel had a driveway 8 feet by 9 feet wide, with continuous air ducts above the ceiling and below the roadway. It was oval in plan, with a major axis of approximately 135 feet and a minor axis of approximately 110 feet, giving a roadway length of 400 feet.

Air for the test was supplied by the mine fan, belt-connected to a steam engine and operated outside the mines. The fan operated normally exhausting, giving upward ventilation in the tunnel. Downward ventilation was accomplished by reversing the direction of the air currents through the reversible housing of the fan, which then operated as a blower.

In the upward ventilation system, air entered the duct under the roadway, passed through adjustable port openings into the con-

tinuous expansion chambers on either side of the roadway, thence into the driveway. In the downward system, air was delivered to the duct in the ceiling, thence through the ports into the upper expansion chambers from which it entered the roadway.

A total of 17 tests were run with cars varying in number from 1 to 8, with concentrations of carbon monoxide in the driveway from 0.5 to 9.4 in 10,000 parts of air, at various temperatures and humidities, and various methods of transverse ventilation. The tests verified the earlier conclusions, and demonstrated that with upward ventilation the exhaust gases crossed the breathing plane of persons in the tunnel but once, while with downward ventilation they crossed this plane twice. There was also a lower concentration of carbon monoxide with upward than with downward ventilation.

Valuable and necessary as were the experiments required to determine the various factors involved in the problem of adequate ventilation for the Holland Tunnel, the data resulting from these preliminary investigations had to be crystallized into tangible units of ventilating equipment.

These are the 84 giant Sturtevant Silentvane fans which are the very lungs of the tunnel. Without such fans blowing in fresh air and exhausting the vitiated air the tunnel could not be made to function.

The Sturtevant Silentvane fans are installed in the ventilation buildings, of which there are two on each side of the river, one at the pierhead line and the other inland. Each land shaft ventilates four sections of tunnel, the adjoining portal sections of each tube, the whole intermediate section to the pierhead shaft where traffic is on a downgrade, and one-half of the parallel section where it is on an upgrade. The buildings over these shafts contain four independent sets of blower and exhaust fans. The pierhead shafts ventilate three sections of tunnel, one-half of each of the 3,400-foot river sections and one-half of the intermediate section where traffic is on the upgrade. In all there are 14 sets of blowers and 14 sets of exhaust fans. Dividing the upgrade sections of the tunnels into three parts gives added ventilation where the greatest amount of carbon monoxide is expected.

There are 28 ducts—14 blower and 14 exhaust, connecting the various sections of the tunnels with the ventilating buildings. Each duct is equipped with three fans, two of which, when operated together, will supply the maximum quantity of air required. Their capacities range from 81,000 to 227,000 cubic feet per minute and they operate at static pressures varying from 0.6 to 3.75 inches of water. This range in pressure and capacity is due to the great difference in length of tunnel ventilated by different sets, those at the outside of the pierhead shafts having 1,700 feet to serve while

the inside fans have only 700 or 800 feet. These fans, during an hour of heavy traffic, will handle 84,000 tons of air, or 1,400 tons per minute. They provide for changing the air in the tunnel 42 times per hour.

The fans are of the backward curved-blade type. Under different conditions, one, two, or three fans may be operated on one tunnel duct at any one time.

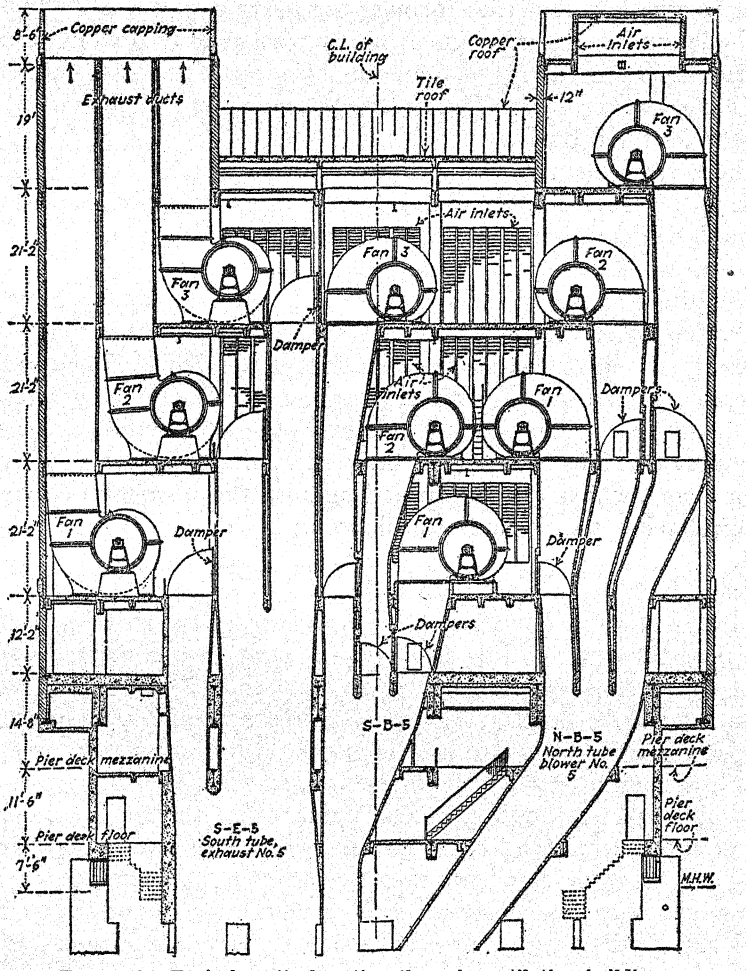



FIGURE 4.—Typical vertical section through ventilating building

They are electrically driven by wound-rotor motors with resistance in the circuit to make it possible to run them at variable speeds. The combined capacities of the motors is approximately 6,000 horsepower, two-thirds of which will be in operation at times of maximum load and one-third in reserve. Chain drives are to be used to make possible speed adjustments or changes in the motors as well as on account of the space limitations in the ventilating buildings.

The placing of the fans is varied to suit the local conditions in the individual buildings. Generally, the exhaust ducts are at the corners of the buildings and supply ducts are in the central portion. Consequently the compartments containing the exhaust fans are located near the corners under the exhaust stacks, leaving the central portions of the fan floors free for intake fans, and the central section of each outer wall for the air intakes. The intakes are made sufficiently large to give low velocities through the louvres.

The louvre blades are made of heavy wire glass to give light to the interior of the buildings as they take up most of the space otherwise available for windows. Heavy bronze screens protect them and also serve to keep out birds.

The arrangement whereby fresh air is drawn in through louvres high up on the sides of the buildings and exhaust air is forced out through stacks which extend 20 feet above the roof insures a complete separation of fresh and vitiated air.

The intake fans and their motors are situated in the open portions of the fan floors where they are accessible. The exhaust fans are, of necessity, inside of chambers at the top of the ducts. Their motors, however, are out on the main floor, the drive shafts being run in to the fans through close-fitting collars in the side plates of the duct. Access to the fans is provided through air locks equipped with air-tight doors which can be opened against the unequal pressure by wedge latches which force the doors open sufficiently to break the seal.

Each duct is equipped with a damper which may be closed when the fan is shut down so that air from the other fans will not be short-circuited through the idle fan. These dampers are motor operated from the control room and are equipped with limit switches.

An unusually flexible system of power supply has been worked out based on the facts that all the motors are in groups of three, also that the maximum power equipments are less than the capacity of the minimum size power cables installed by the local companies. Three cables from the New York side and three from the New Jersey side are run to the bus bars in each ventilating building, thus giving one motor in each set a separate cable connection to power supply on each side of the river. Interconnection at the bus bars makes it possible to cut in any or all motors on each cable. Thus connected, each motor may be supplied with power by six independent cables, each capable of carrying the entire tunnel load; and, as there are at least two independent sources of power at each end of the tunnel, continuity of power supply is absolutely assured.

As the transformers are located in the ventilating buildings where smoke from an oil fire might be drawn into the ventilating system, air-cooled instead of oil-cooled transformers are used.

Each fan is provided with a control switch at the motor for emergency or repair use. Further local control is provided at the switchboard in each ventilating building, and complete operating control is provided at the main switchboard in the administration building where, by a system of signal lights, it will be possible, at all times, to tell what motors are in operation.

Air from the intake fans is forced down into the longitudinal duct under the roadway of the tunnel. From there it is fed through flues 10 to 15 feet apart into a continuous expansion chamber above the curb line at each side of the roadway, the flow of air into this chamber being controlled by adjustable slides over the flue openings. The outer side of the expansion chamber is a copper-steel plate which can be adjusted to give an opening of widths varying from ¾ inches to 1¾ inches through which fresh air flows into the tunnel.

Vitiated air is drawn off through openings through the ceiling into the exhaust ducts. These openings are spaced 10 to 15 feet apart and are from 3 to 6 feet long. They, also, are provided with slides by which the opening can be adjusted to meet the local requirements for air circulation.

By this arrangement of supply and exhaust ports, fresh air supplied to the roadway mixes with the warmer gases and rises to the ceiling where the exhaust ports are located.

There will be no longitudinal movement of air in the tunnels except that induced by the movement of vehicles, nor will there be any objectionable winds such as would be created by longitudinal ventilation. Tests made with smoke bombs showed that even large quantities of smoke will not spread far from the point of origin, but will rise quickly to the ceiling and be taken out. Similiarly, in case of a fire the hot gasses will rise to the ceiling, where they will be drawn off. There will not be the same danger of spreading the fire from car to car as there would be with longitudinal ventilation.

As part of the studies for the ventilating equipment, numerous tests in relation to fire were made, both in the test tunnel at Bruceton and at the laboratories of manufacturers of fire-fighting equipment. These tests included the burning of an automobile drenched with gasoline and with gasoline spilling from a hole in the tank on the car to determine how quickly such a fire could be put out with the hand extinguishers to be placed in the tunnel.

As a check upon the air conditions in the tunnel, automatic carbon monoxide recording devices are installed in each exhaust duct which will make a continuous analysis of the gases and record it graphically in the control room of the administration building in New York. There, by observing the chart, the operator can increase or decrease the fresh-air supply as traffic conditions change in the tunnel.

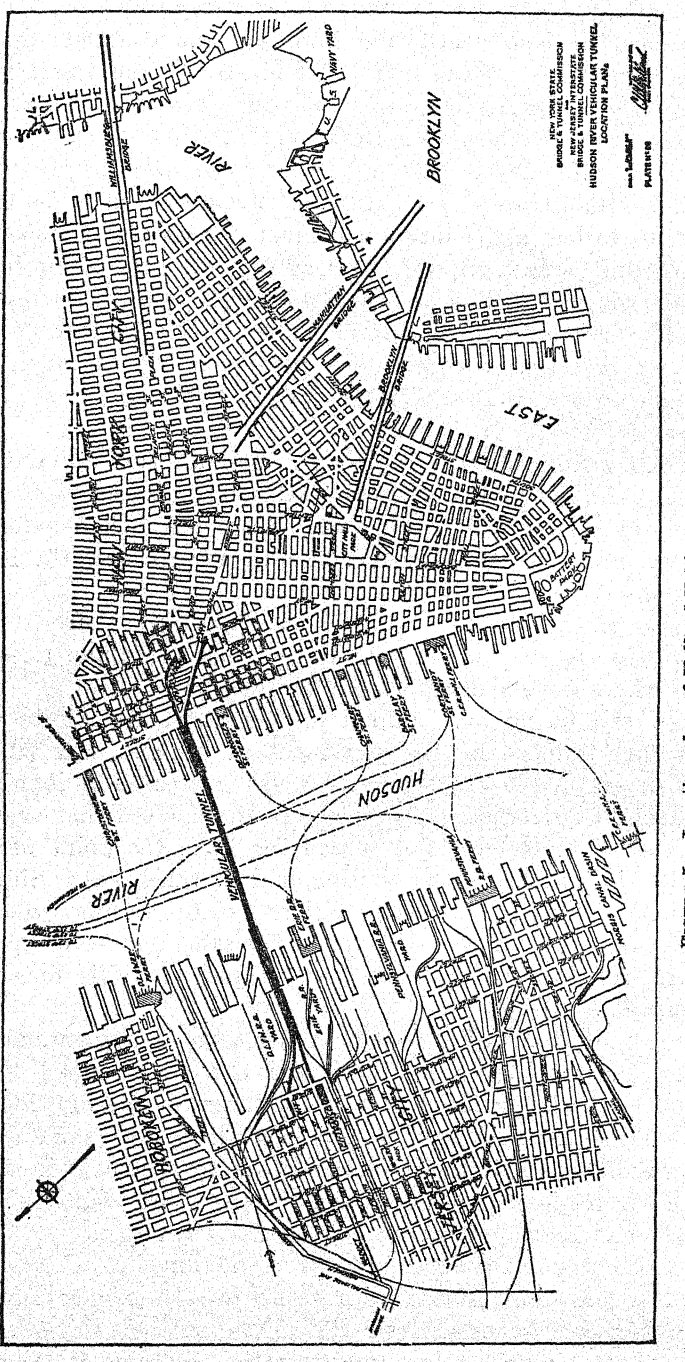



FIGURE 5.—Location plan of Holland Vehicular Tunnel

That the construction of the Holland Tunnel was no easy task is evidenced by the great increase in both time and money required for its completion. The original plans called for an expenditure of approximately $28,000,000 and for completion in 1924, or three and one-half years. Actual expenditures have run 50 per cent greater, and as this is written, the opening will not be until the fall of 1927.

Yet this is not surprising. Although the shield method of construction has been described in this story as if it were a relatively simple operation, many difficulties had to be overcome in bringing the work to a successful conclusion. The proceedings involved in the taking of real property at entrances and exits, changes in the grades of streets, the closing of a portion of Eleventh Street in Jersey City, negotiations with the railroads at the Jersey City end for the acquisition of parts of the railroad yards, all took time. It was not always easy to harmonize the views of the State Commissions. Alterations necessarily had to be made in the preliminary plans as further information resulted from investigation and experience.

That the undertaking cost the lives of its first two chief engineers, not from accident, but from the drain on their vital energy, is perhaps the most striking evidence of the magnitude of the undertaking.

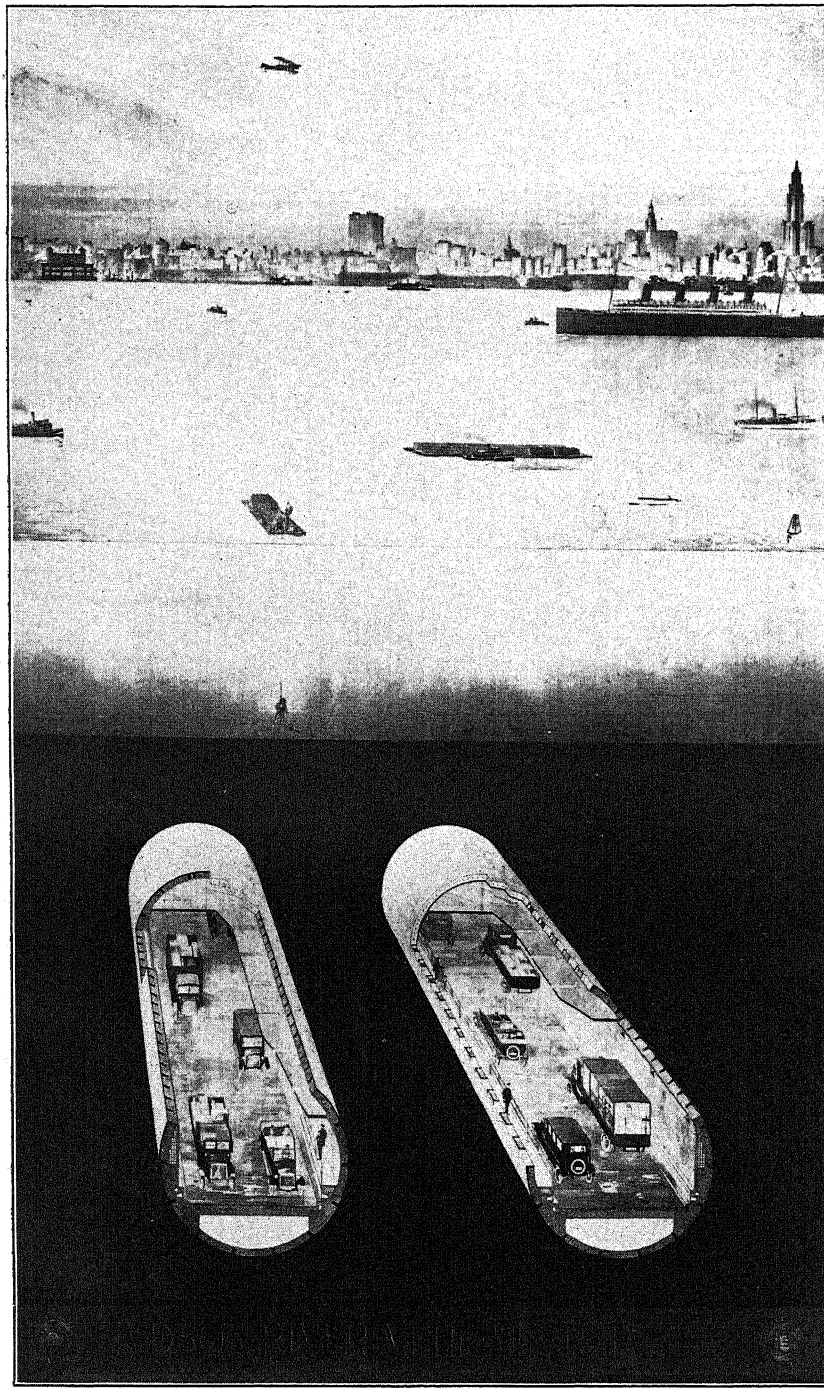


CLIFFORD MILBURN HOLLAND

Genius of the Holland Tunnel and its first chief engineer, in memory of whom the tunnel was named.



SITE OF THE HOLLAND TUNNEL, LOOKING WEST FROM NEW YORK CITY

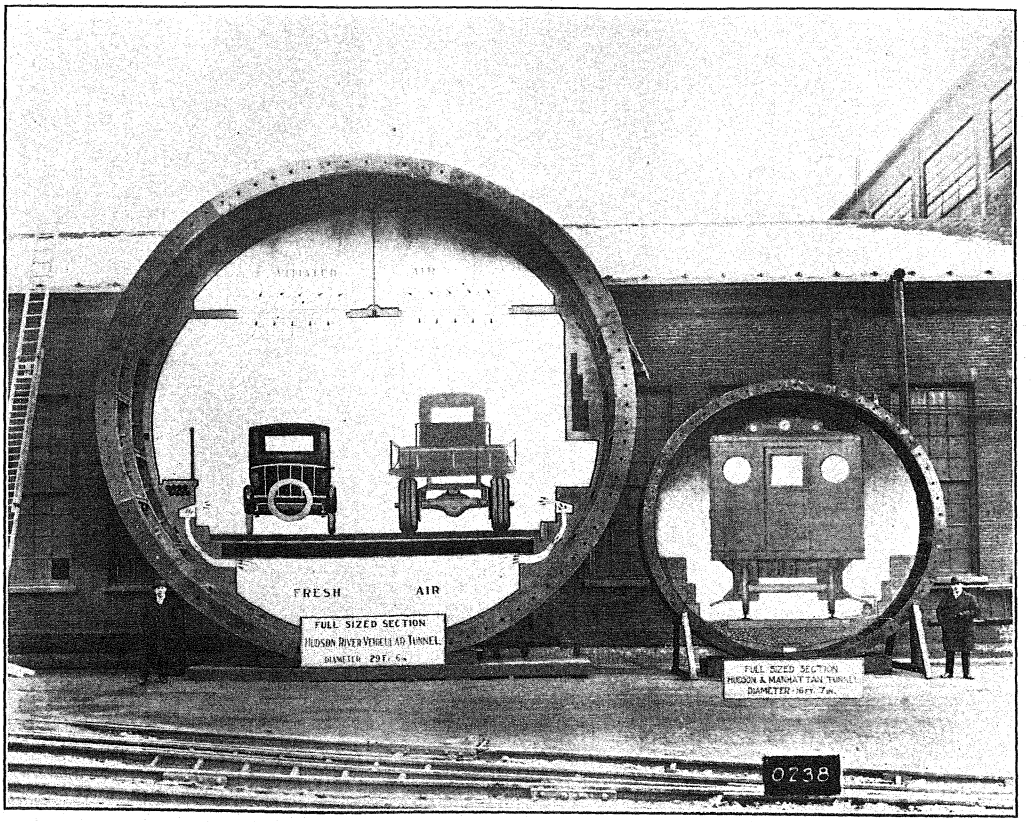


SECTIONAL VIEW OF HOLLAND TUNNEL UNDER THE HUDSON RIVER, LOOKING TOWARD NEW YORK CITY



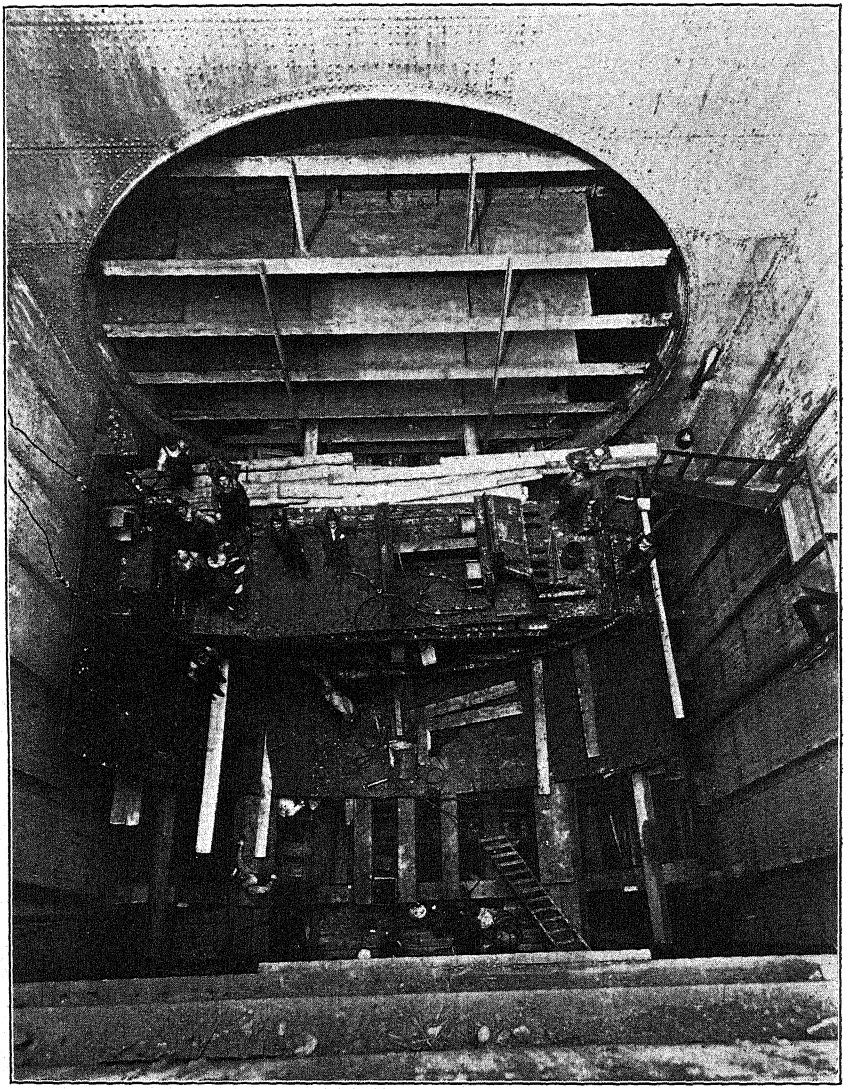
MILTON H. FREEMAN

Who succeeded Mr. Holland as Chief Engineer, and who died in 1925.



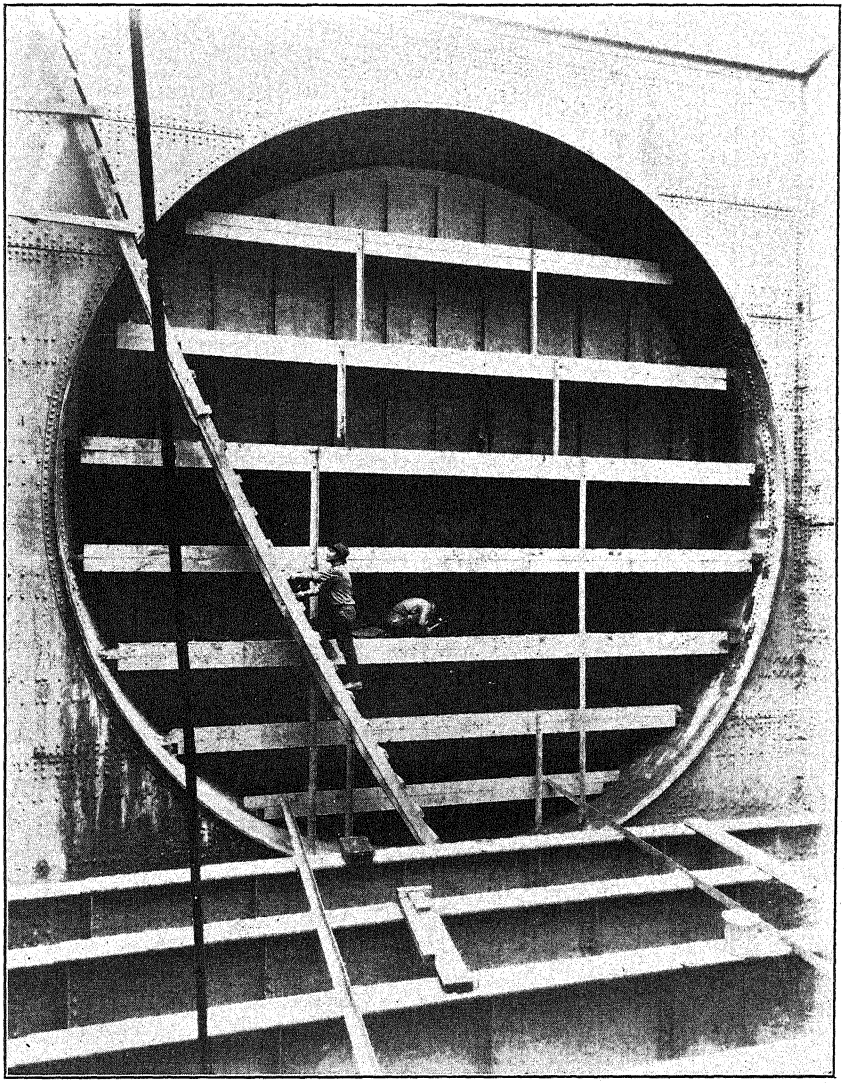

HOLLAND TUNNEL AND HUDSON & MANHATTAN RAILROAD TUNNEL

Full-sized section of Holland Tunnel (diameter 29 feet 6 inches) and full-sized section of Hudson & Manhattan Railroad Tunnel (diameter 16 feet 7 inches). Rings weigh 16,630 pounds and 5,670 pounds per linear foot, respectively.



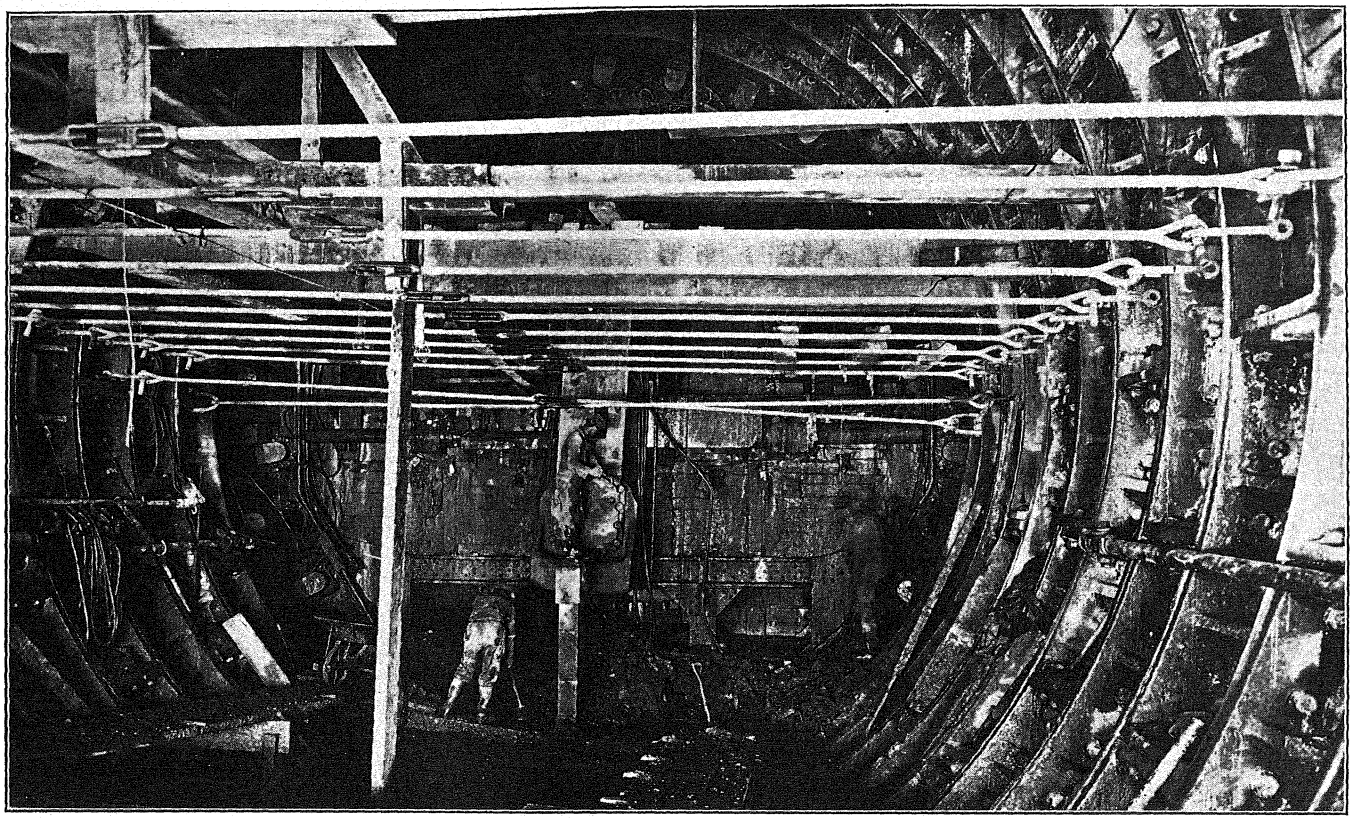
ASSEMBLING SHIELD IN CANAL STREET SHAFT

View looking down into shaft, showing bulkhead in west side wall.



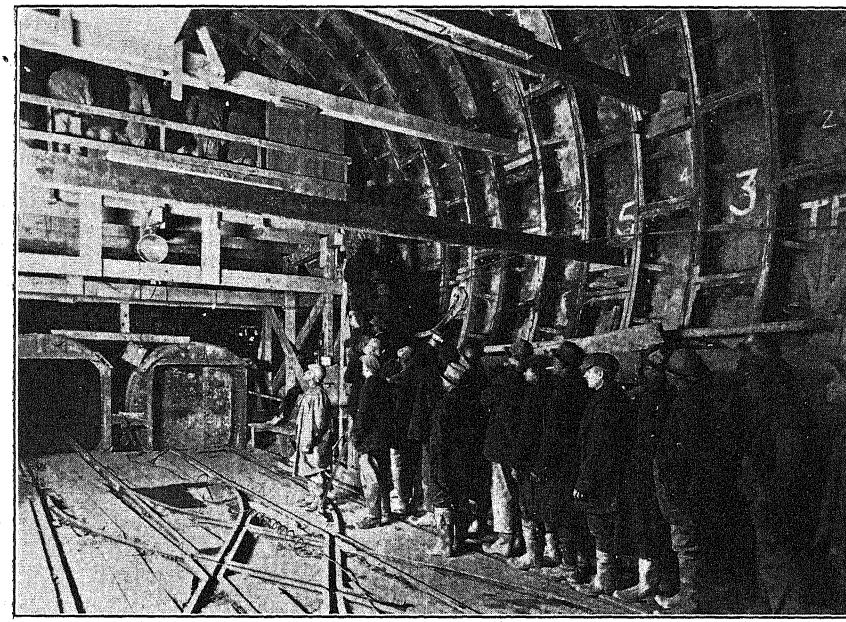
LAND SHAFT CAISSON AT SPRING STREET, NEW YORK CITY

Showing steel bulkhead in west side wall through which shield advanced after erection.



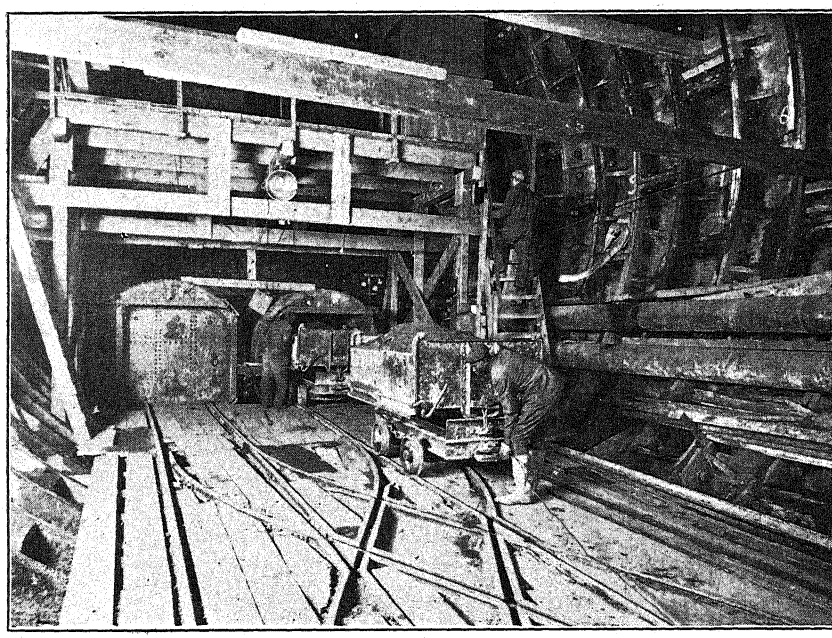
SHIELD, SOUTH TUNNEL, CANAL STREET AT WEST STREET, NEW YORK CITY

View of rear end of shield in place and temporary bulkhead. Tunneling operations temporarily suspended and air pressure removed in order to remove shaft dec. and place cages in shaft and air locks in tunnel.

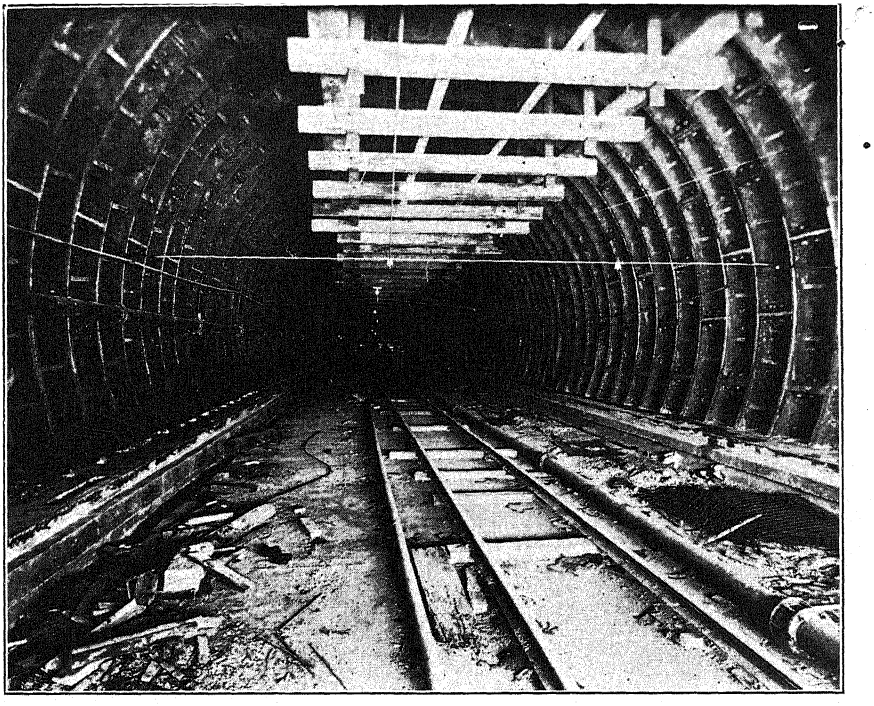



1. GANG OF "SAND HOGS" IN LINE

Waiting to check in for work in compressed air. Canal Street land shaft and air locks, South Tunnel.

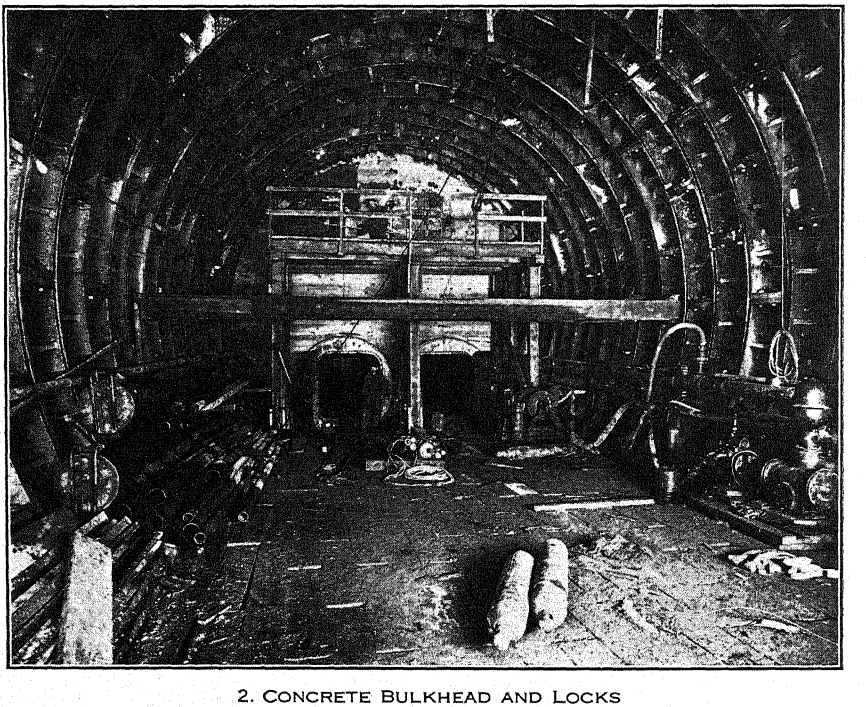


2. HAULING A CAR OF MUCK OUT OF A MUCK LOCK, SOUTH TUNNEL



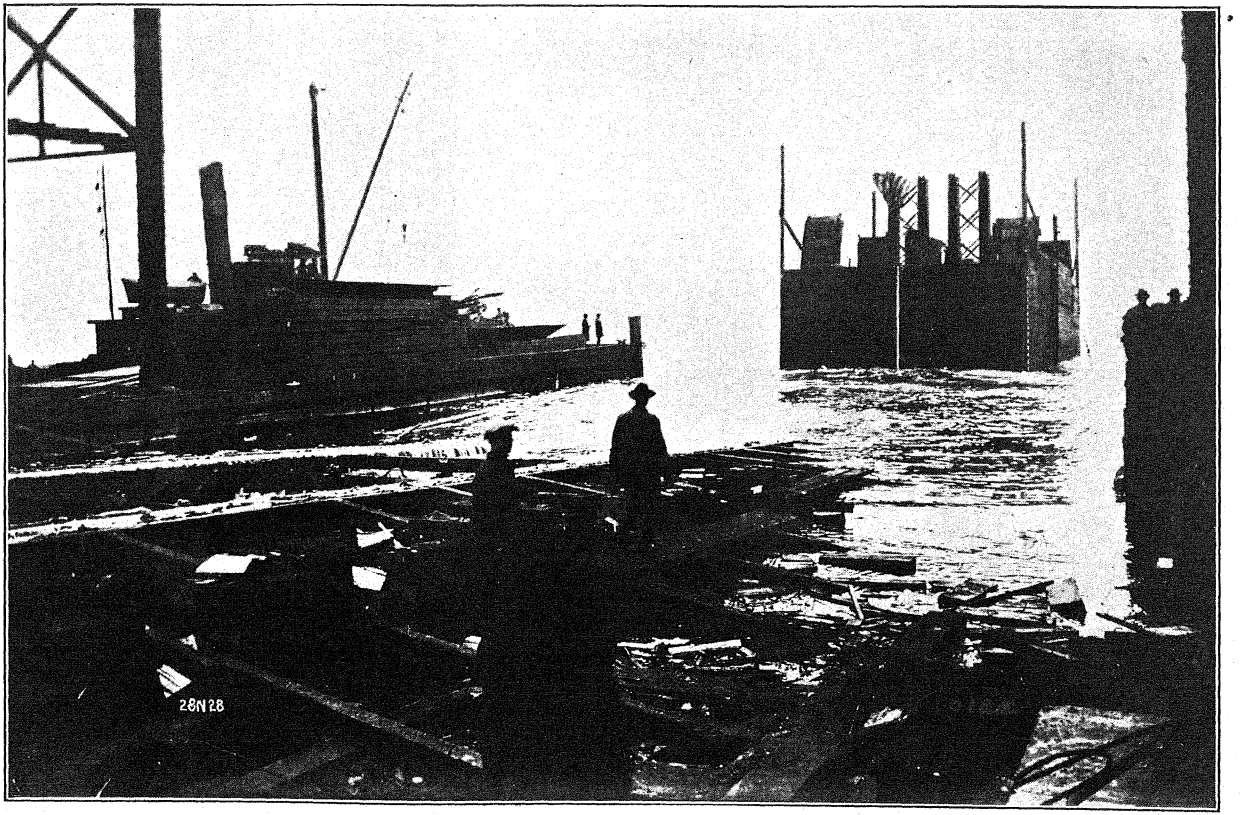
1. CONCRETE ROADWAY

Beginning of sidewalk, and reinforcing of sidewalk, North Tunnel. View shows construction track on roadway and roof rebolting and calking platform.



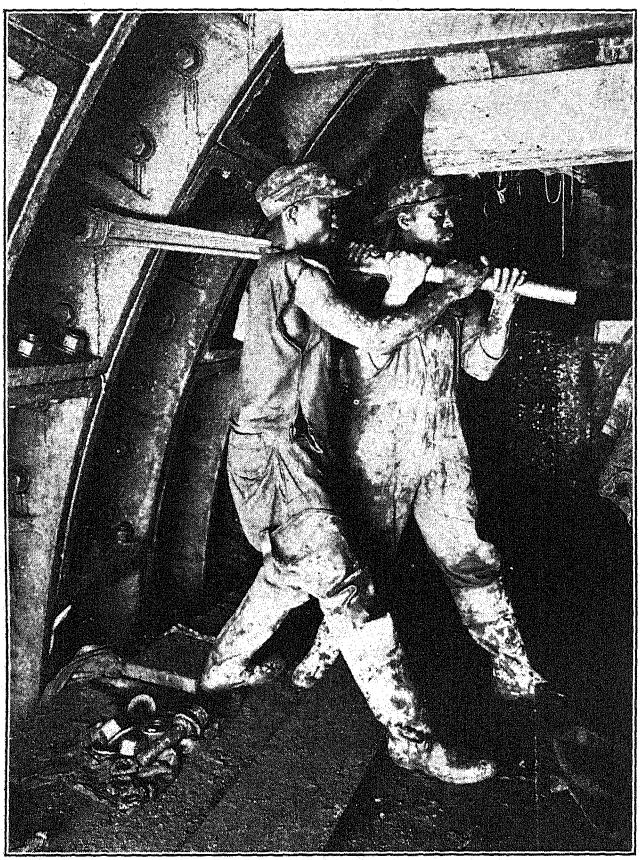
2. CONCRETE BULKHEAD AND LOCKS

South Tunnel, Canal Street, New York City.

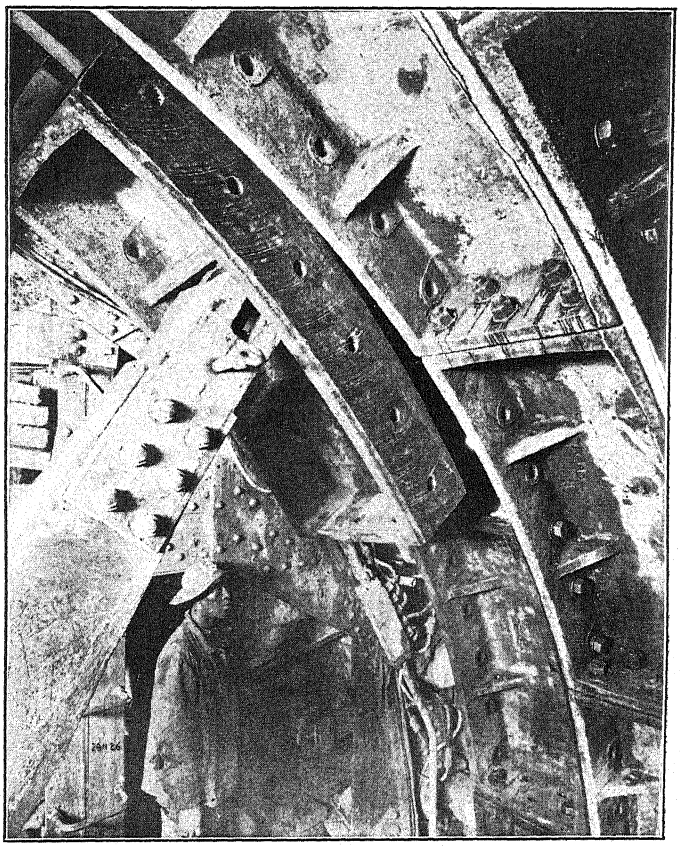



NEW JERSEY RIVER SHAFT CAISSON, JUST AFTER LEAVING THE WAYS

Caisson launched at Mariners Harbor, Long Island, floated into position and sunk.

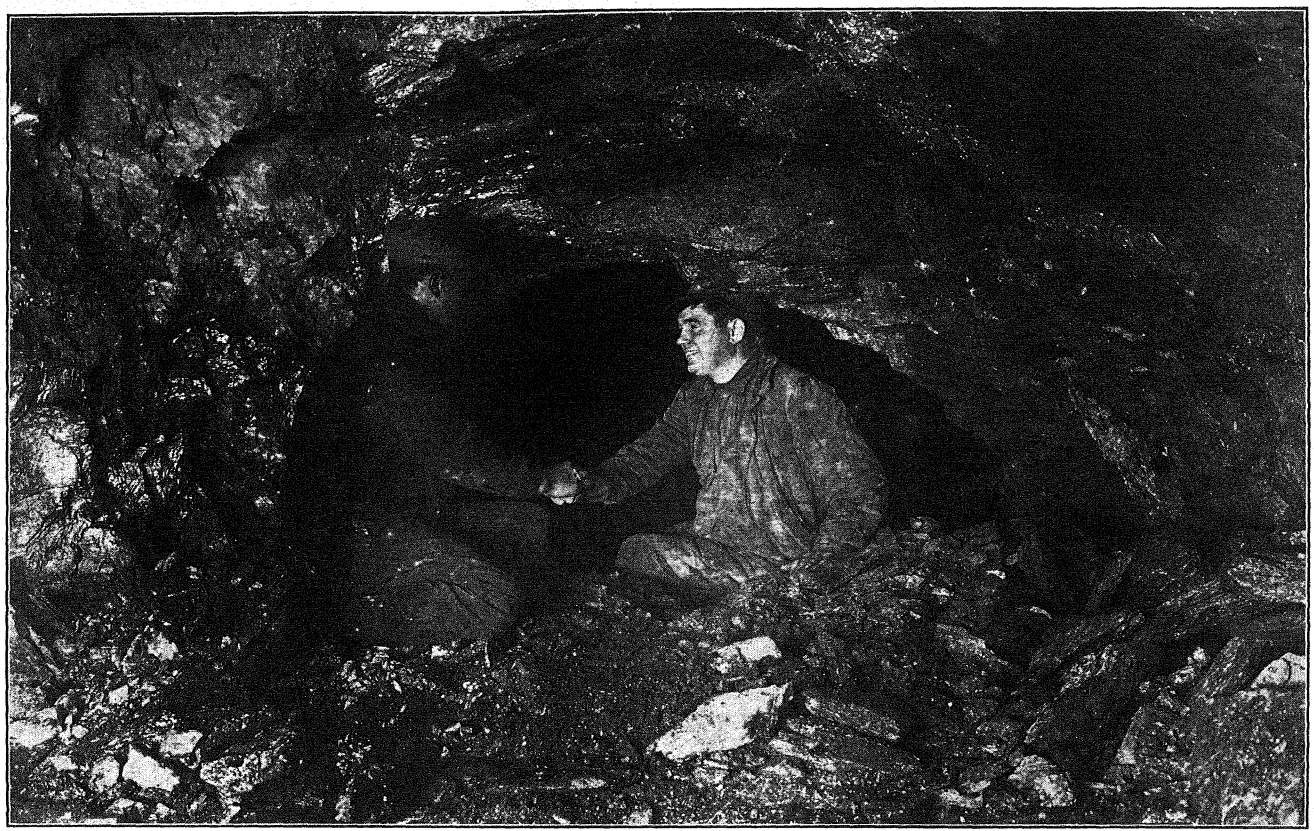


TIGHTENING BOLTS IN TUNNEL LINING, NORTH TUNNEL, BY MEANS OF RATCHET WRENCH. EACH BOLT WEIGHS 10 POUNDS



ERECTOR ARM

Swinging iron segment into place in tunnel lining, South Tunnel New York City.

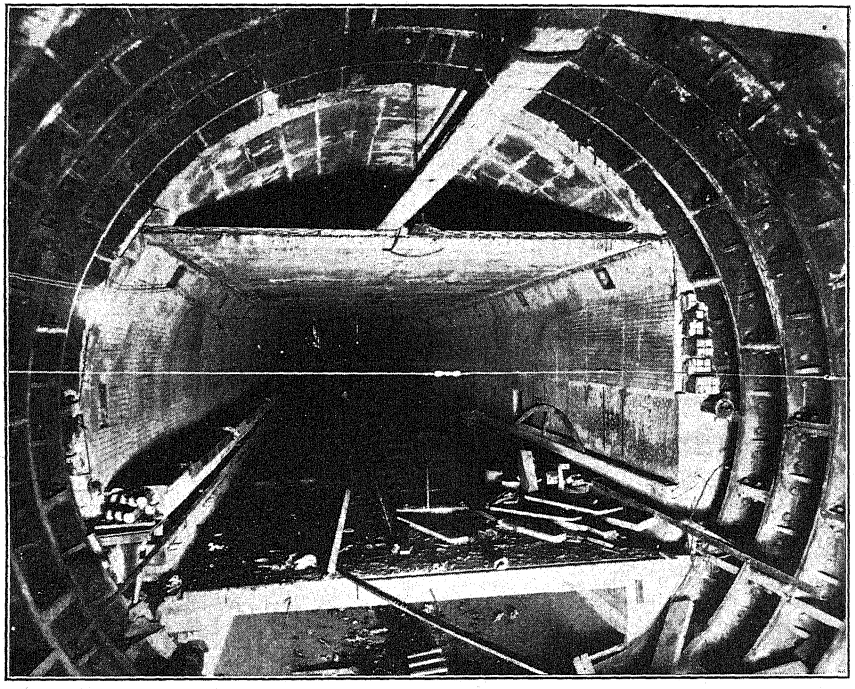


HOLING THROUGH

Tunnel superintendent Harry Redwood, of New York side, shaking hands with Norman Redwood, of New Jersey side, North Tunnel.

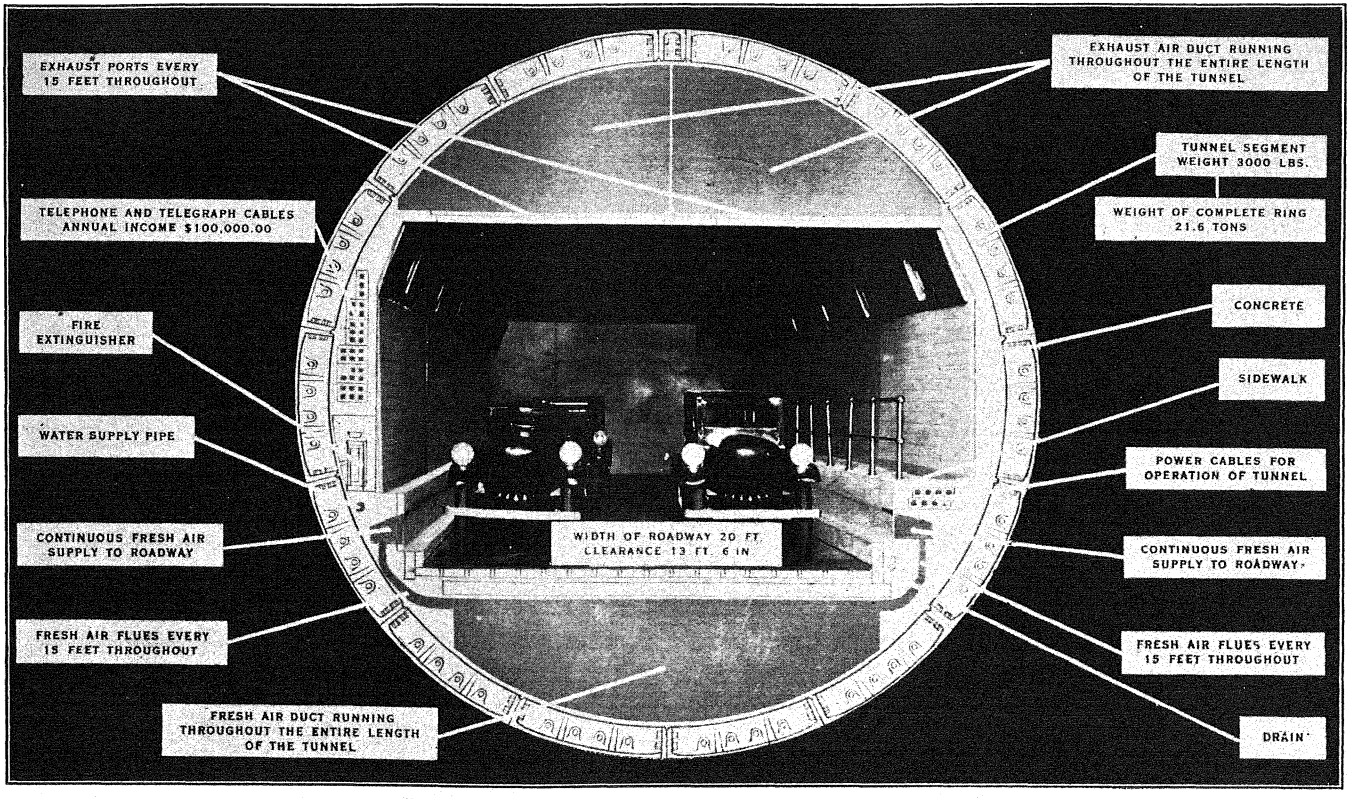



CURVE IN SOUTH TUNNEL UNDER WEST STREET, NEW YORK CITY (RADIUS 1,000 FEET). SHOWING COMPLETED RINGS OF CAST-IRON LINING

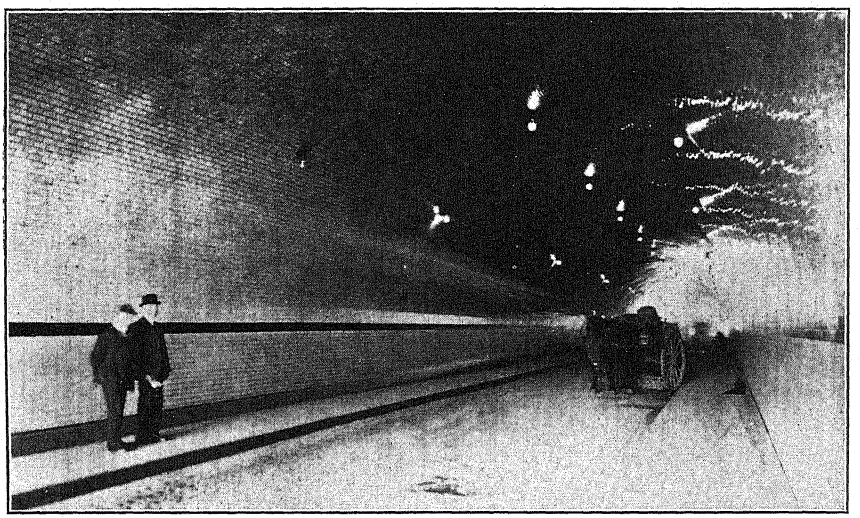


CONCRETE CONSTRUCTION IN SOUTH TUNNEL

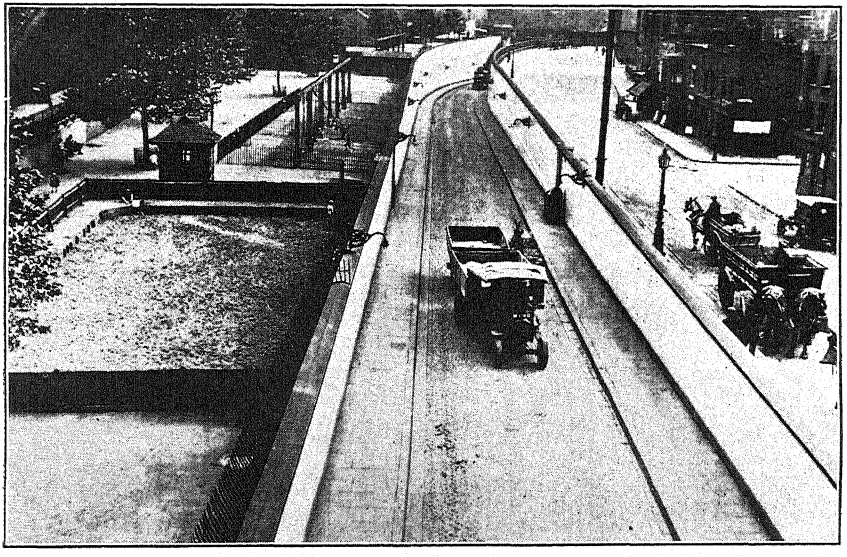
Showing a typical cross section of concrete lining and details. The upper and lower arcs of the tunnel form the ventilating ducts.



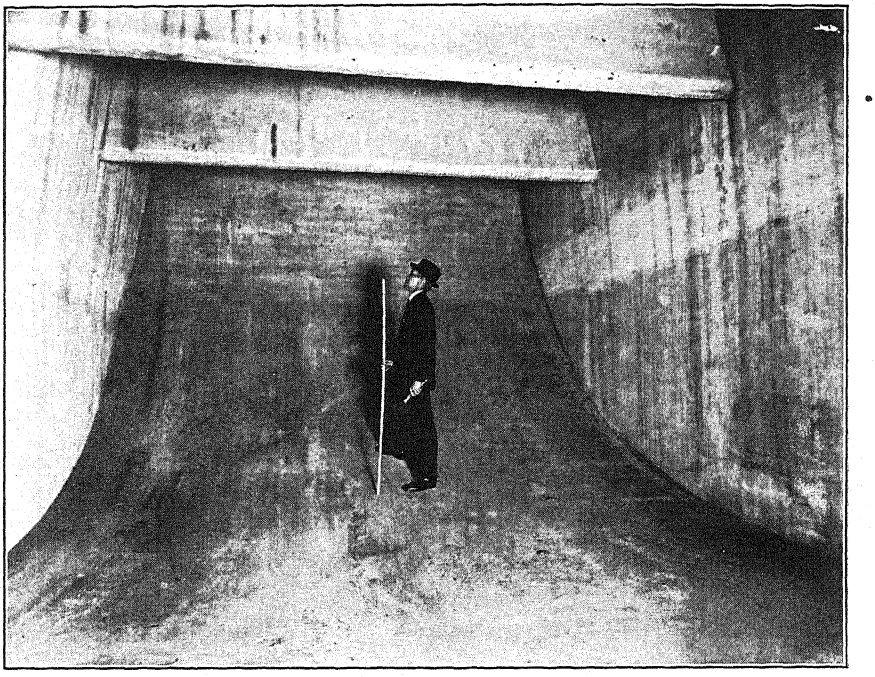

MODEL OF THE HOLLAND TUNNEL SHOWING MANY OF THE HIDDEN DETAILS



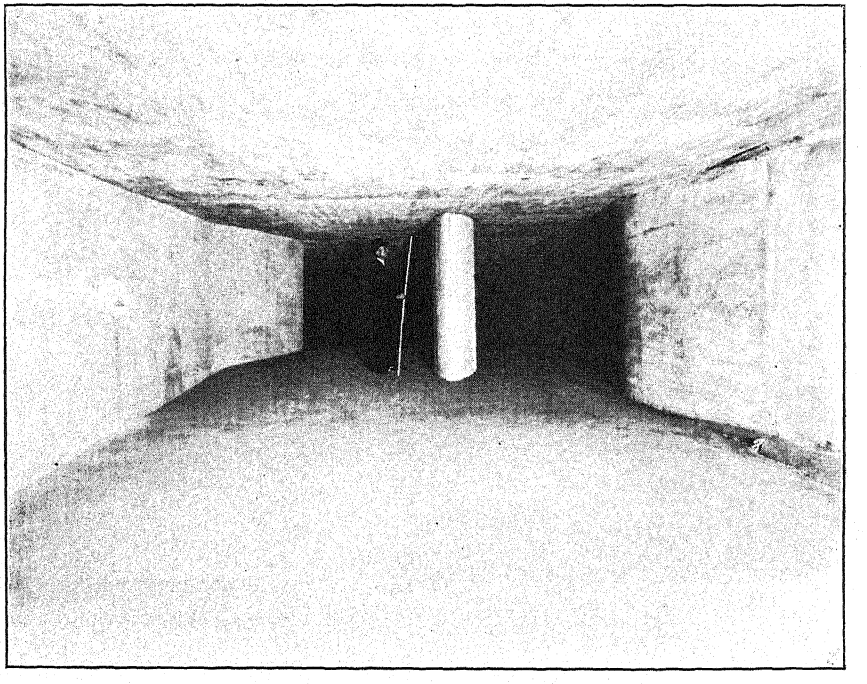
REST AND REFRESHMENT IN ROTHERHITHE TUNNEL, RIVER THAMES, LONDON, ENGLAND



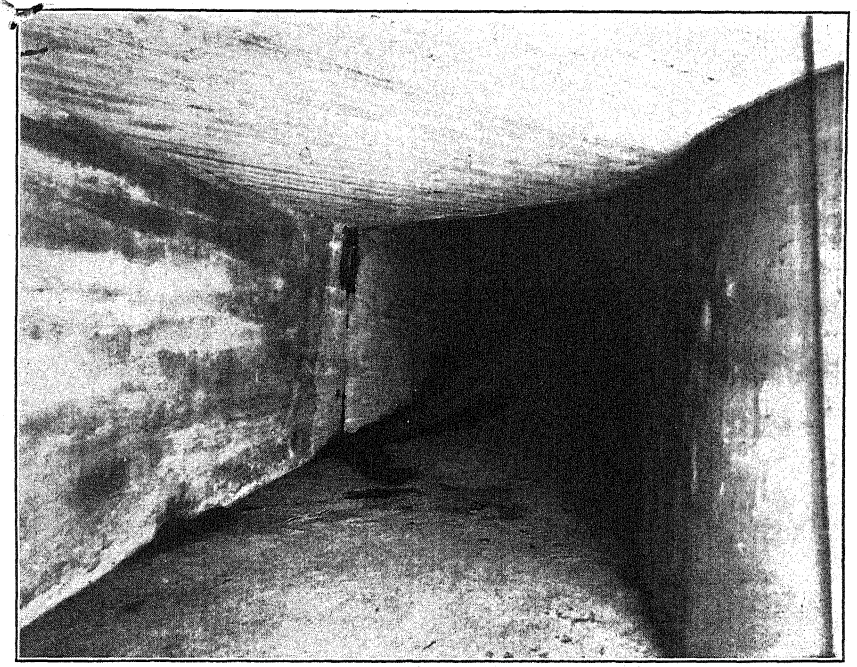
APPROACH TO THE BLACKWALL TUNNEL, RIVER THAMES, LONDON, ENGLAND



1. EAST BLOWER AIR DUCT
In land ventilation building, New York City, showing curved back and vanes.

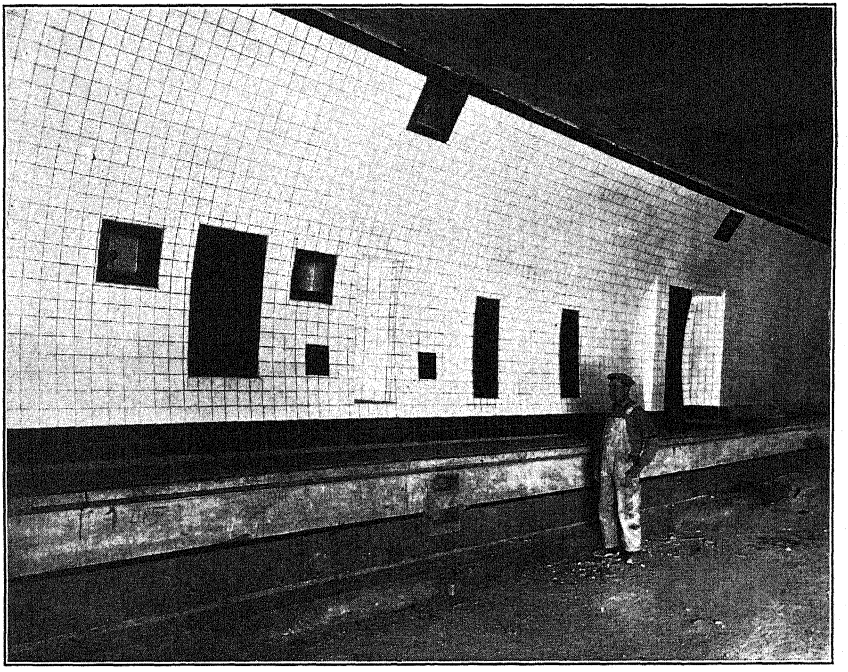


2. EAST BLOWER AIR DUCT
Land ventilation building, New York City.



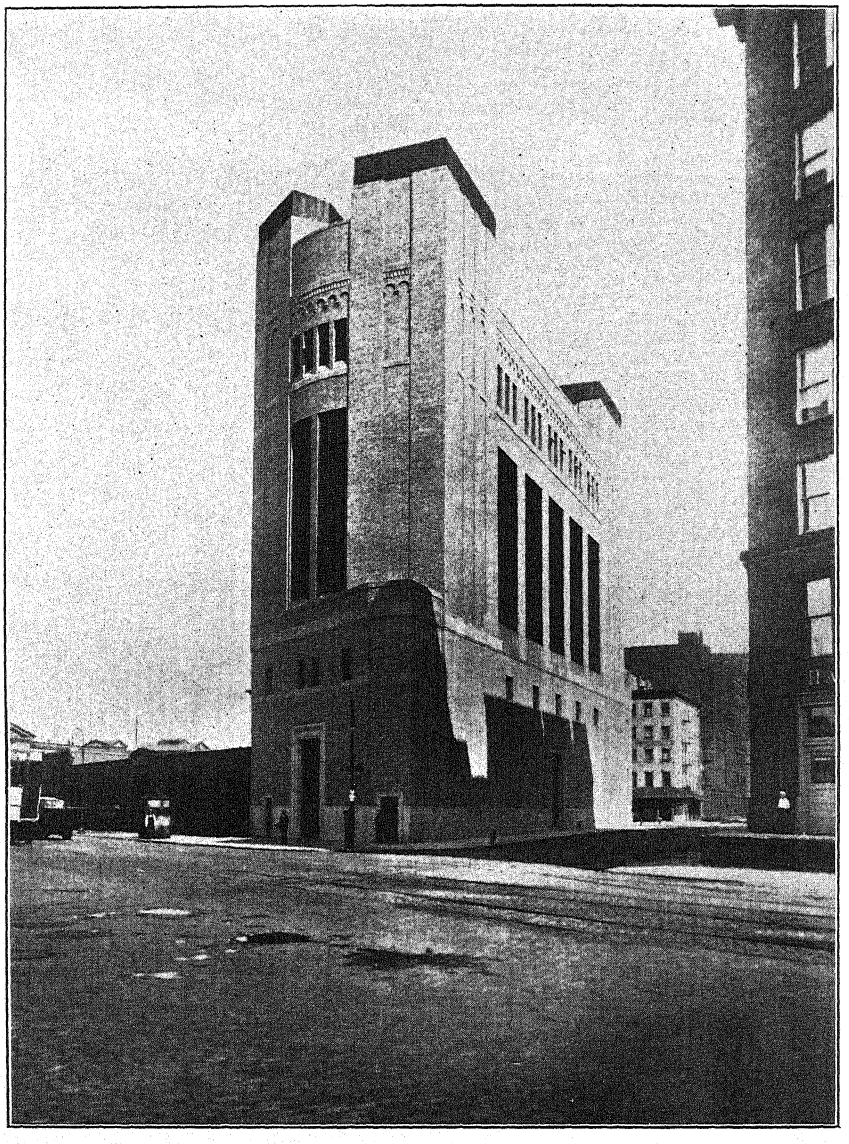
1. FRESH-AIR DUCT IN SOUTH TUNNEL, NEW JERSEY SIDE

Showing the beginning of the transition from its position under the roadway to its position alongside the tunnel.



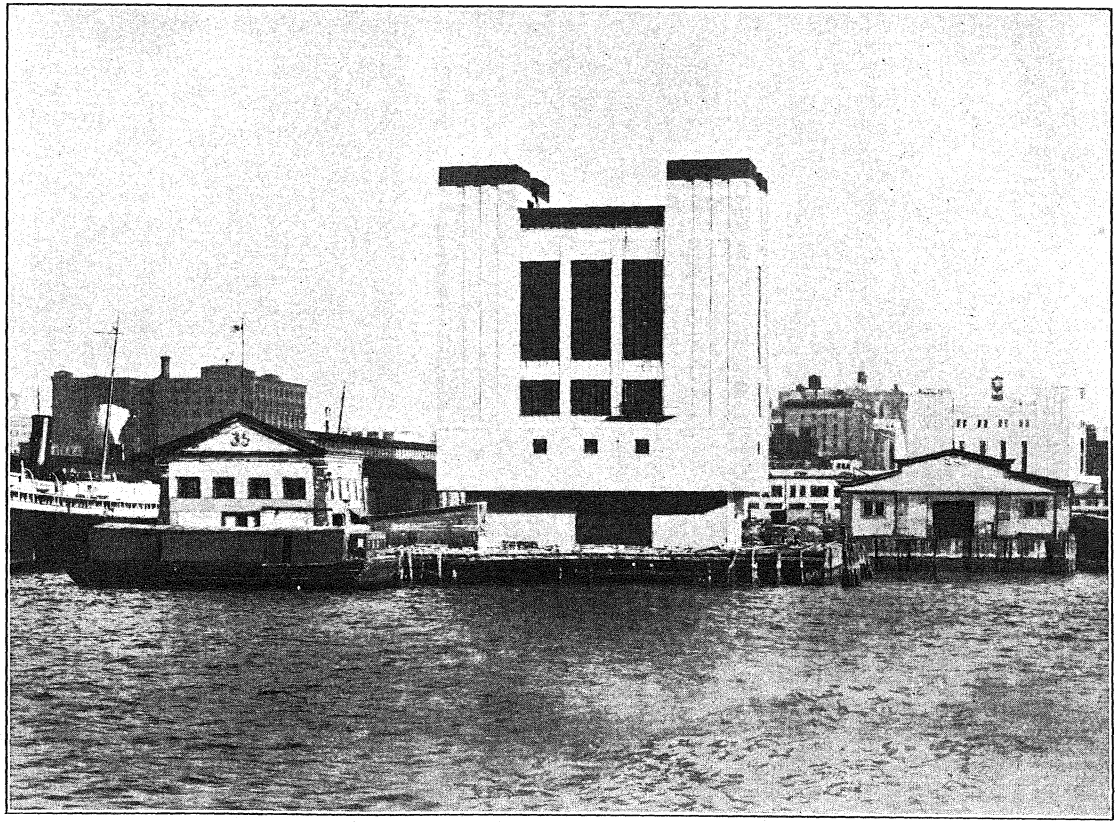
2. TILE AND BRONZE WORK

Left to right: Bronze door to relay niche with telephone and fire-alarm boxes on each side; tiled refuge niche with fresh-air outlet on each side, two fire-extinguisher niches; tiled opening to mid-river sump.



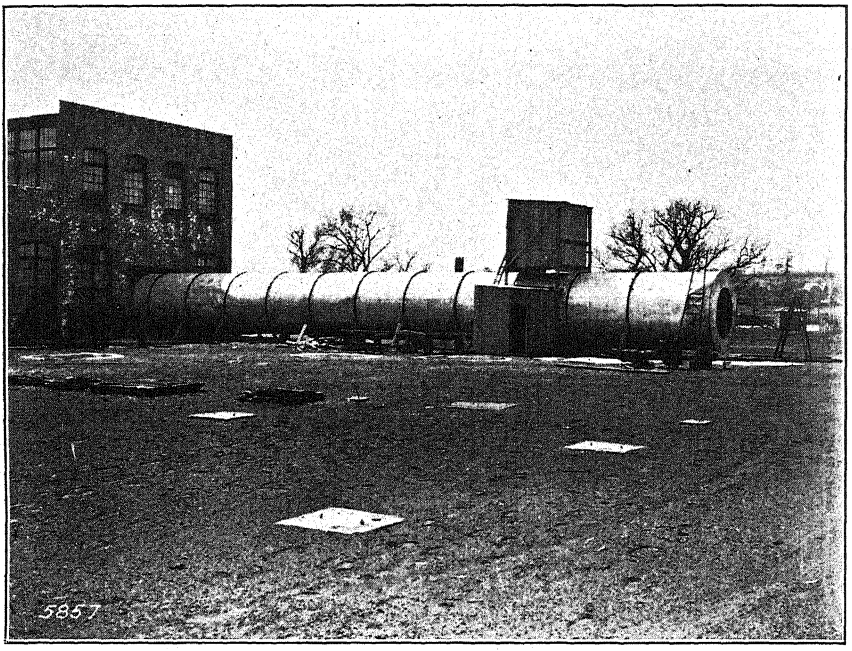
LAND VENTILATION BUILDING

West side of Washington Street, Canal Street to Spring Street, New York City.

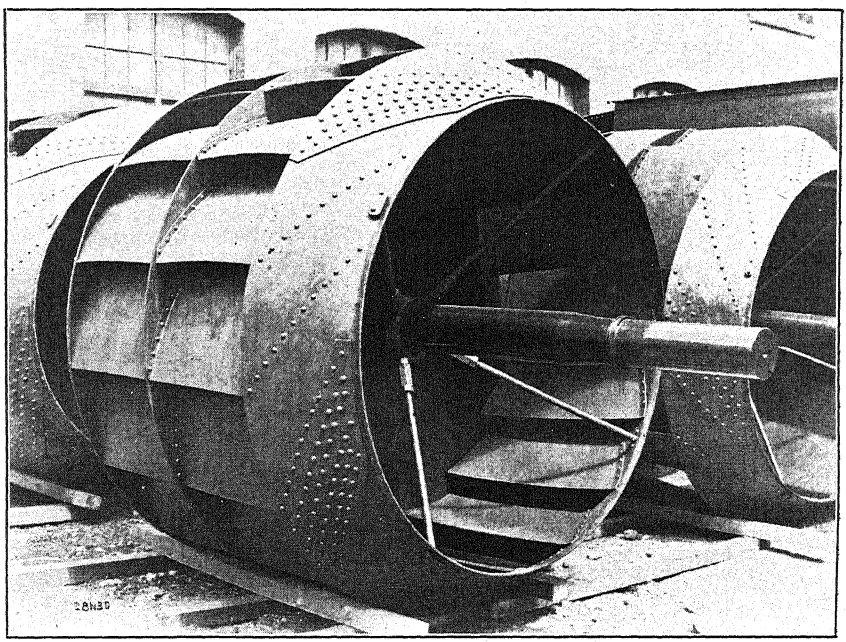



RIVER VENTILATION BUILDING

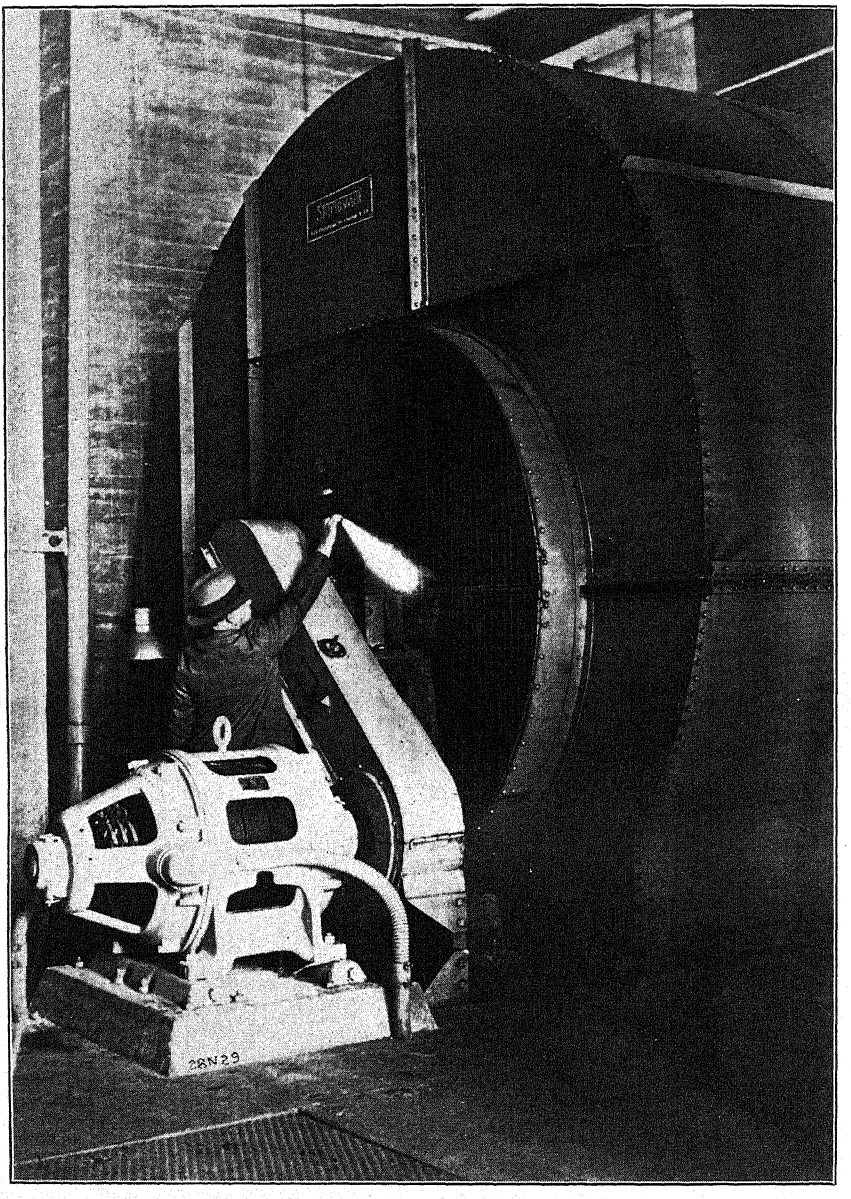
Pierhead line between Piers 34 and 35, North River, New York City.



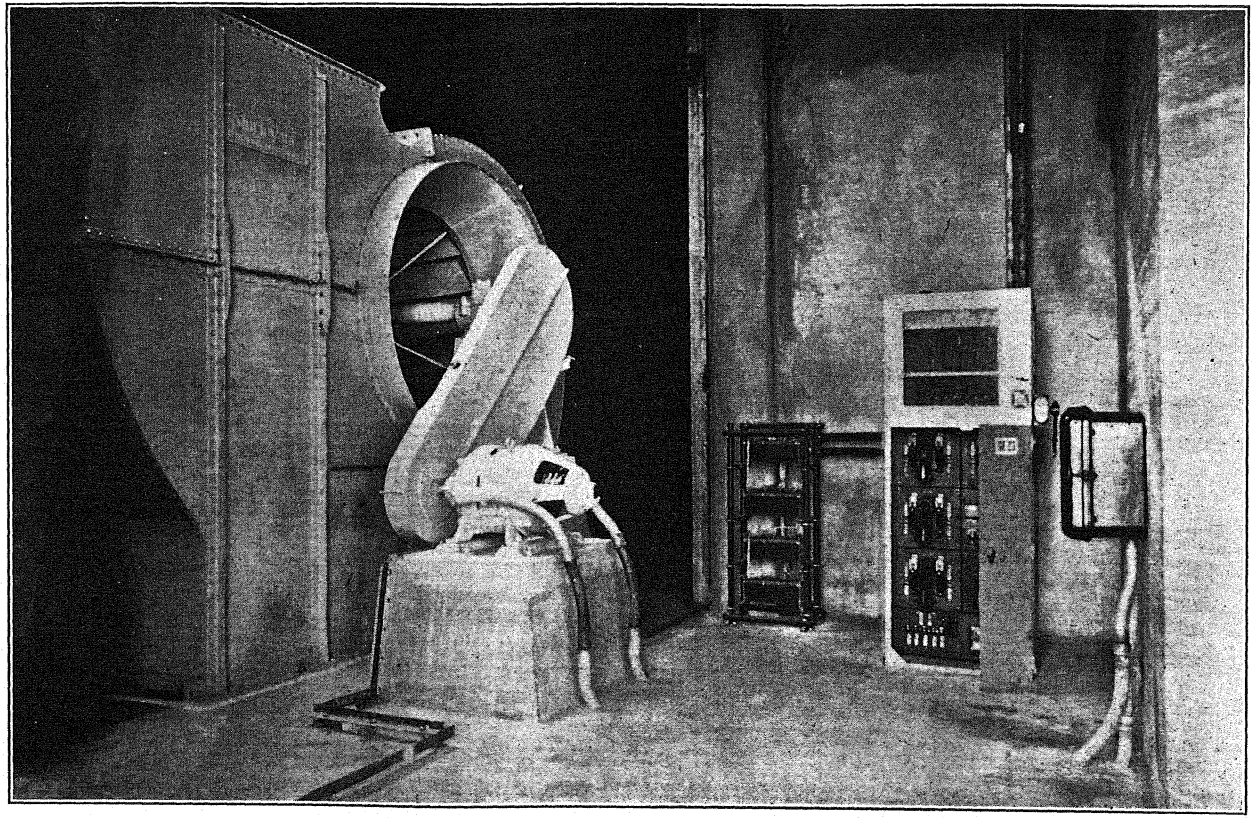

SPECIAL APPARATUS ERECTED AT HYDE PARK PLANT OF B. F. STURTEVANT CO.
Used in testing Sturtevant silent-vane fans for the Holland Tunnel.



STURTEVANT SILENT-VANE FAN WHEELS FOR THE HOLLAND TUNNEL

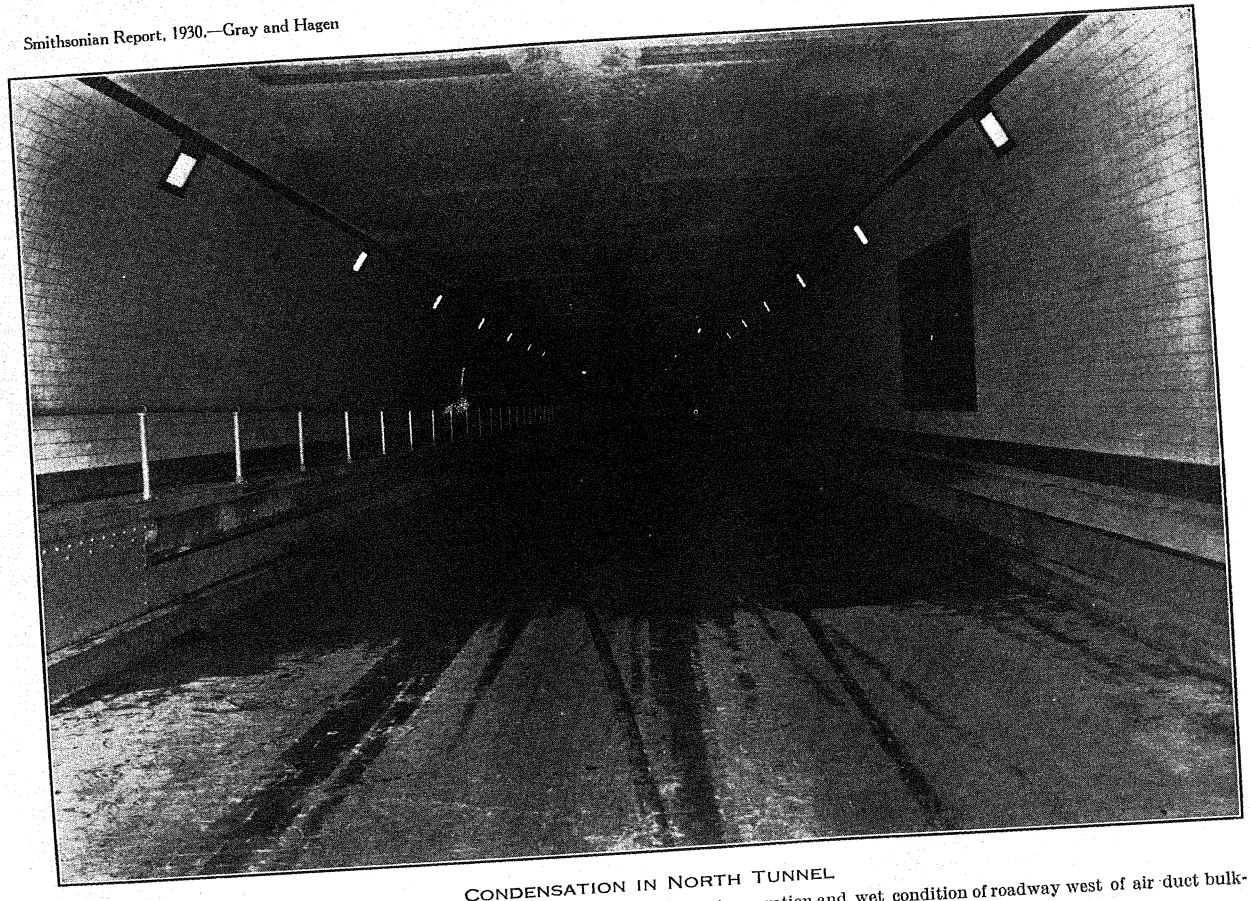


ONE OF THE 84 STURTEVANT SILENT-VANE FANS WHICH ARE THE LUNGS OF THE HOLLAND TUNNEL



EXHAUST FAN UNIT IN NEW JERSEY LAND VENTILATION BUILDING

Showing typical arrangement of exhaust fan, motor, chain casing, resistors, control cabinet, and local control box.



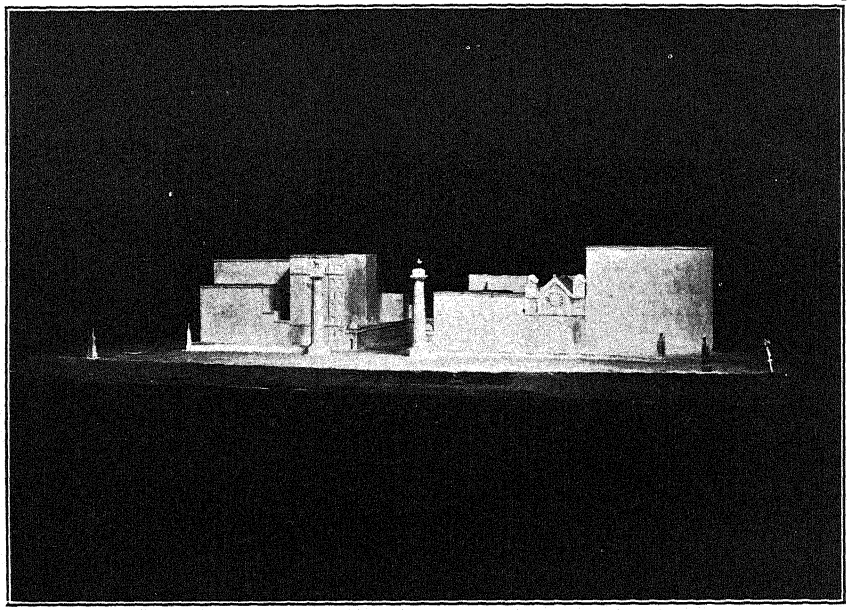
CONDENSATION IN NORTH TUNNEL

View showing dry condition of roadway east of air duct bulkhead where fans were in operation and wet condition of roadway west of air duct bulkhead where fans were not in operation.



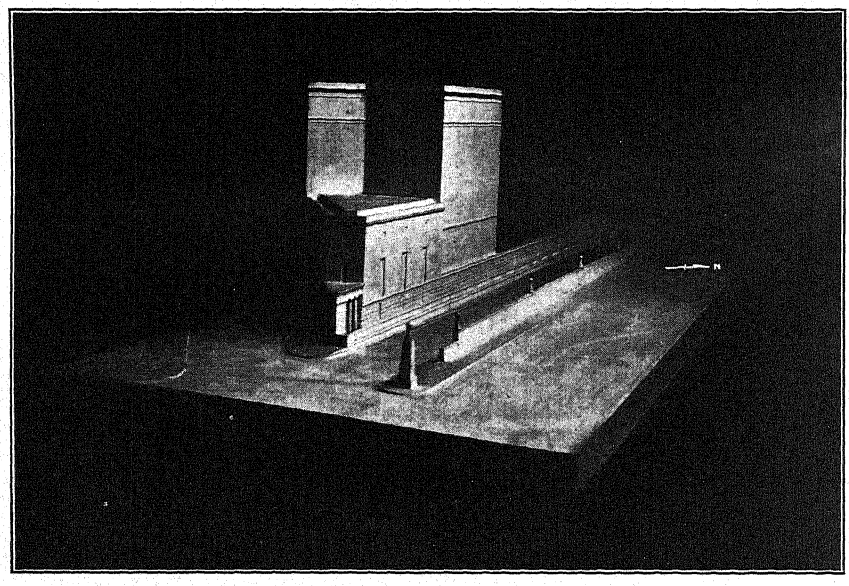
OLE SINGSTAD, CHIEF ENGINEER

Under whose direction the Holland Tunnel was brought to successful completion.



1. MODEL OF ENTRANCE TO TUNNEL, NEW YORK CITY

Looking north-northwest across entrance plaza which comprises north half of block between Broome and Watts Streets.



2. MODEL OF EXIT FROM TUNNEL, NEW YORK CITY

Looking northwest along Canal Street.



JESSE WALTER FEWKES

# JESSE WALTER FEWKES[1]

By JOHN R. SWANTON AND F. H. H. ROBERTS, JR.

[With 1 plate]

The death of Jesse Walter Fewkes removes one who was an outstanding influence in the formative period of American archeology, particularly the archeology of our great Southwest. He was born at Newton, Mass., on November 14, 1850, of parents whose ancestral lines in America extended back to the seventeenth century. In 1871 he entered Harvard and he graduated four years later with honors in natural history, besides being elected to membership in Phi Beta Kappa.

In 1874, while he was still an undergraduate, two papers on electrical subjects were published by him, but the year before he had come under the influence of Louis Agassiz in the latter's school at Penikese Island, Buzzards Bay, and this experience probably led him to turn his attention wholly to zoology. At any rate he took up graduate work in natural history and, after receiving the degrees of A. M. and Ph. D. in 1877, he continued zoological studies at Leipzig under Rudolph Lueckart between 1878 and 1880. Later he spent several months in Naples and at Villa Franca on the south coast of France as holder of the Harris fellowship. After his return to America he received an appointment as assistant in the Museum of Comparative Zoology at Harvard where, from 1881 to 1889, he had charge of the collections of the lower invertebrata. In 1881 he accompanied Alexander Agassiz to Key West and the Dry Tortugas for the study of marine life and two years later he visited the Bermudas on a similar quest. Every summer, from 1884 to 1887, he was assistant in charge of the younger Agassiz's marine laboratory at Newport, R. I., but in the spring of 1887 he pursued scientific studies at Santa Barbara, Santa Cruz and Monterey, California, as a guest of Augustus Hemenway, of Boston, and in the summer of 1888 he studied in Paris and engaged in field work in marine zoology at Prof. Lacaze Duthier's zoological station at Roscoff, Brittany.

Doctor Fewkes's visit to California proved to be a turning point in his career, for it was then that he came in contact with the culture

[1] This article is expanded from one by John R. Swanton published in Science, July 4, 1930, Vol. LXXII, No. 1853.

of the Pueblo Indians, which excited in him an interest still further stimulated by the enthusiasm of Mrs. Mary Hemenway. In 1889 and 1890 he undertook field work among the Zuñi Indians of New Mexico, and in the latter year he made use of a phonograph—the first time, it is believed, that it was so employed—in the recording of Indian music. In 1891 be became director of the Hemenway Southwestern Archeological Expedition and editor of the Journal of American Archeology and Ethnology, established to publish the results of its investigations. During the same year he began those studies of Hopi ceremonials for which he became especially noted and which probably constitute his most enduring contribution to American anthropology.

These investigations were greatly facilitated by his initiation into the Antelope and Flute priesthoods. The happy relationship thus established enabled him to witness many secret rites from which the ordinary observer was barred and his descriptions of many of the ceremonials were the first to be published. His account of the Hopi snake dance, which appeared in 1894, was a pronounced factor in spreading the knowledge of this striking rite and stimulating popular interest in it. In the following years he prepared additional reports on various phases of it and although innumerable papers on the subject have been written in recent years, his works still furnish the background and source of information for many of the descriptions of the ceremony.

The Hemenway expedition having been invited by the Spanish Government to participate in the historical exposition held at Madrid in 1892–93 to commemorate the discovery of America by Columbus, Doctor Fewkes was given charge of the exhibit and he was a member of the jury of awards. In recognition of these services he was honored by Maria Cristina, queen regent of Spain, with the decoration "Isabel la Catolica," grade of knight. In 1894 King Oscar of Sweden presented him with a gold medal, "Litteris et Artibus," for his work in anthropology.

After returning to America, Doctor Fewkes resumed investigations in the Southwest, but they were soon brought to an end temporarily by the death of his patroness, Mrs. Hemenway, in 1894. The collections made under his direction during this period are in the Peabody Museum at Cambridge.

In May, 1895, Doctor Fewkes received an appointment as ethnologist in the Bureau of American Ethnology at Washington along with the honorary title of collaborator in the division of ethnology in the United States National Museum, and the connection which he established with the bureau at this time continued unbroken until his resignation and retirement from active service in 1928.

This constituted a turning point in his career in another direction because, although he continued to publish the results of his work

among the living Hopi for many years afterward, his field excursions now became mainly archeological. From 1895 until 1901 the scene of these investigations was in and near the Hopi country in Arizona.

It was during the summer of 1895 that he made a survey of the ruins along the Rio Verde and excavated at the Hopi ruins of Awatobi and Sikyatki. His collection of specimens from the latter sites contains some of the finest examples of the ceramic art ever found in the Southwest. While conducting the Sikyatki investigations Doctor Fewkes fostered the beginnings of a renaissance in Hopi pottery making. Nampeo, a young woman from the village of Hano, was a constant visitor at the scene of the excavations and was so fascinated by the beauty of the pottery being unearthed that she began copying the forms and style of decoration. As a result of Doctor Fewkes' encouragement and advice she was so successful in her endeavors that other women turned to the ancient wares for their inspiration. From that time to the present day the pottery made in the various villages has been distinctly of the Sikyatki style.

The field seasons of 1896 and 1897 were spent in the Little Colorado and upper Gila districts. The excavations conducted at that time furnished data for the most elaborate and extensive reports yet printed on the region. Doctor Fewkes had no sooner reached the field in 1898 than the whole Hopi area was swept by an epidemic of smallpox and he was forced to return to Washington.

In the autumn of 1899 his attention was temporarily diverted from archeological researches when he returned to the Hopi villages to complete some of the ethnological studies begun in earlier years. He spent the winter living with the Indians and obtained much valuable information which appeared in subsequent reports on their ceremonies. The spring of 1900 found him continuing his reconnaissance of Arizona ruins. The following year was devoted to a study of the information obtained in the field and the preparation of a report on his work. He did find time, however, to make a trip into western Texas and northern Chihuahua, Mexico, during the summer of 1901. While in Mexico he visited the ruins known as Casas Grandes and made what at that time was the most critical and extensive study of them ever attempted.

As a result of the Spanish-American War considerable popular and scientific interest was focused on Cuba, Porto Rico, and the West Indies, and Doctor Fewkes was among those who desired to conduct investigations in the area. Accordingly he devoted portions of the years 1902, 1903, and 1904 to researches in the islands. The region furnished him much in the way of specimens and information and he was able to prepare an extensive report dealing with his discoveries.

The season of 1905 found him carrying his investigations to the mainland and doing work in northeastern Mexico.

With the passage of the Lacey Act in 1906 providing for the creation of public parks or national monuments a new era dawned in the history of Southwestern archeology, and the services of Doctor Fewkes were at once enlisted by the Department of the Interior for the exploration and restoration of ruins upon the public domain. In 1906 and 1907 he explored and repaired the famous Casa Grande ruins of southern Arizona, but in 1908 transferred his labors to the Mesa Verde National Park in southwestern Colorado and continued there through the field season of 1909. The work of the latter two expeditions consisted of the excavation and repair of the two large cliff dwellings called Spruce-Tree House and Cliff Palace. His reports, magazine articles, and lectures on these spectacular ruins attracted many visitors to the park and greatly simulated public interest in the subject of Southwestern archeology.

In 1909 and 1910 he visited large undescribed cliffhouses in the Navaho National Monument, northern Arizona, and prepared a publication on them. This turned the attention of archeologists to the region and in the years immediately following several expeditions were sent out from various institutions to conduct investigations in the ruins.

In 1911, he returned to the West Indies, visiting Cuba, the Isle of Pines and Grand Cayman, and, in 1912, the Lesser Antilles, but the following spring he went to Europe where he spent part of his time studying the West Indian collections in German and Danish museums. While in Europe at this time he made a trip to Egypt in order that he might observe the methods employed by the egyptologists in their excavations. He was especially interested in the technique of repair which they had developed and was able to adapt certain features of it to his later work in the Southwest.

The summer of 1914 found him again in the Southwest. This time his activities were centered in the Mimbres Valley in southwestern New Mexico and as a result of his investigations the highly pictorial form of ceramic decoration peculiar to the region became generally known. Publication of papers on this pottery led many institutions to send parties into that field. Digging there has continued unabated to the present day.

The summer of 1915 was spent on the Mesa Verde in southern Colorado. During the season two ruins, Sun Temple and Oak-Tree House, were uncovered. Sun Temple, because of its unusual shape and indications that it had been erected solely for ceremonial purposes, attracted a great amount of attention and illustrated articles about it were printed by many newspapers and magazines throughout

the country. No single ruin on the mesa caught the public fancy as did Sun Temple and up to the time of his withdrawal from active participation in archeological affairs Doctor Fewkes was called upon to answer many letters of inquiry regarding the structure.

Early in the field season of 1916, Doctor Fewkes returned to the Hopi country in Arizona with the hope that he might locate some of the villages which Indian traditions attributed to clan migrations during the period antedating the founding of the Hopi towns. From there he worked eastward into western New Mexico and conducted a reconnaissance in the vicinity of Gallup. Completing his survey of the ruins in that section he proceeded to Mesa Verde where the remainder of the season was devoted to conducting excavations in the Mummy Lake group of ruins. The remains of the pueblo structure uncovered were given the name Far View house. This piece of work was considered important because it showed that there was no outstanding difference between the houses built in the large natural caverns and those erected on the mesa tops. At the close of the work on the mesa Doctor Fewkes made a trip into the Uintah reservation in eastern Utah for the purpose of determining the northern limits of the pueblo cultures. On this survey he observed and reported many tower and house ruins which previously had been unknown.

In 1917 he spent the field season conducting a reconnaissance in the McElmo district of southwestern Colorado. This was done in an effort to discover, if possible, what the relation between the many towers and circular structures of that section and the Sun Temple ruin might be. He found little of help in that respect but did establish the fact that most of the ruins scattered throughout the area were comparable to the ruin on the mesa which he called Far View House. The problems involved became so intricate that he returned to the same region in 1918 and continued his survey in an effort to obtain further information. As a result of this he was able to postulate the development of the great communal dwellings out of small house and village clusters. Curiously enough, at that time neither he nor other investigators in the Southwest placed much emphasis on this theory of the evolution of the house. The work of recent years conducted by younger men has shown that his idea was a sound one and that he had foreseen what excavation has actually shown.

On March 1, 1918, Doctor Fewkes was appointed chief of the bureau of which he had so long been an active member. However, this appointment scarcely interrupted the course of his field investigations.

In 1919 he continued his work on Mesa Verde excavating the ruin known as Square Tower House and the remains of a pit dwelling which was designated Earth Lodge A. The latter was interesting

because it was one of the first of that type brought to light in the Southwest. Since then many pit houses have been located and uncovered and the type has become widely known.

The summer of 1920 was devoted to the excavation of additional ruins on Mesa Verde. The most outstanding of these was the one which Doctor Fewkes called New Fire Temple. It is considered one of the most remarkable cliff dwellings in the park, if not in the whole Southwest. Like Sun Temple, it had been erected purely for ceremonial usage and from the evidence he obtained in uncovering it Doctor Fewkes was convinced that it had been dedicated to the sacred fire and probably to a form of fire worship. The other ruins investigated that season were Cedar-Tree Tower and Painted Kiva House.

The following season, 1921, he completed the excavation of Far View House, repaired and capped its walls to protect them from the weather and also repaired and capped the walls of Sun Temple. During the course of his investigations in the Southwest, beginning with his work at Casa Grande in Arizona, Doctor Fewkes always made it a point to repair and protect the ruins which he excavated. So persistent was he in his belief that ruins should be protected once they were uncovered and so untiring was his advocacy of that pratice that in the course of time most of the institutions engaged in extensive work in the region followed his lead.

The field seasons of 1921 and 1922 were the last ones which Doctor Fewkes spent at Mesa Verde. His work then consisted of the excavation and repair of several small ruins, Pipe Shrine House and One Clan House being the most significant. Both represent an earlier stage of development than that of the large cliff-dwellings and furnished him with data upon which to draw conclusions concerning the sequence of building types in the park.

At the beginning of his work on the Mesa Verde Doctor Fewkes started a custom which became popular with the visitors to the park. Each night a group would gather around his camp fire and he would tell them of the Indians, of his finds, of his views and ideas concerning the ruins which he was excavating. With the passing of the years the number of visitors rapidly increased and a special place had to be provided for the evening camp fire so that all who were desirous of hearing the talks might attend. As a result of this Doctor Fewkes had a tremendous influence in arousing an interest in the story of the Southwest and creating an appreciation for the excavators and their problems.

The creation of the Hovenweep National Monument, including the McElmo district in Colorado, in 1923 and the Wupatki National Monument in Arizona in 1925 may be attributed to Doctor Fewkes' untiring efforts to have those districts set aside and preserved by the Government.

His last outdoor work of importance was the excavation of Elden Pueblo, near Flagstaff, Ariz., in 1926.

As chief of the Bureau of Ethnology Doctor Fewkes also found time to interest himself in the archeology of the southeastern part of our country which he visited several times. His most important undertaking here was the excavation of the Weeden Island mound, near St. Petersburg, Fla., in the winter of 1923–24, and it is characteristic of his archeological optimism that his very last expedition consisted in a "reconnaissance" of the Piedmont region of South Carolina in June, 1927, looking toward more extensive investigations at some later period.

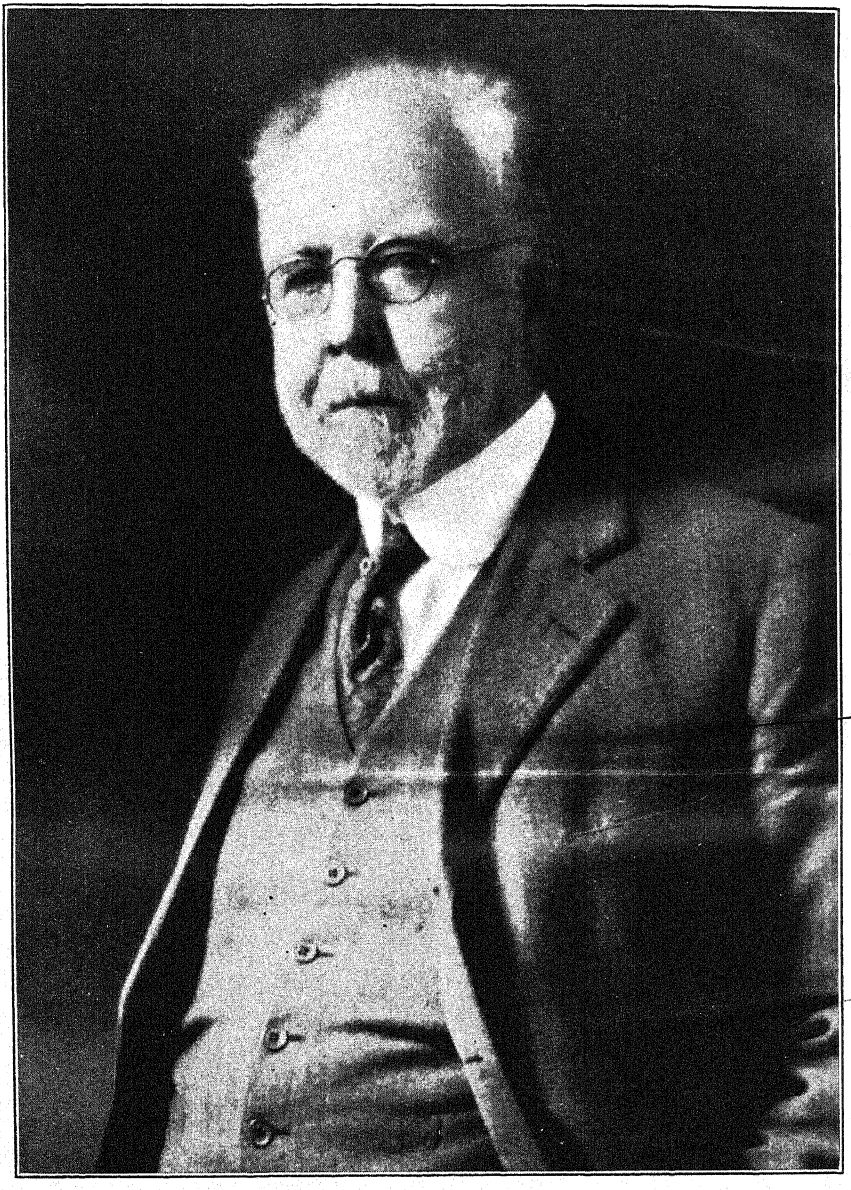
In April, 1925, Doctor Fewkes had to undergo a severe operation and, while he returned to the field, as noted, in 1926 and 1927, he never recovered fully from its effects. After his return from the South in 1927 he suffered a fall and, as a result of it, became so much weaker that on January 15, 1928, he resigned as chief of the Bureau of American Ethnology but continued on its staff until November. His death took place on May 31, 1930, his wife, who had been his constant field companion, preceding him by a few weeks.

Doctor Fewkes was a member of the National Academy of Sciences and an honorary or corresponding member of many scientific societies, American and foreign. He was secretary of the Boston Society of Natural History from 1889 to 1891, vice president and chairman of section H of the American Association for the Advancement of Science in 1901 and again in 1915, president of the Anthropological Society of Washington in 1909 and 1910, president of the American Anthropological Association in 1911 and 1912, and for more than 30 years he was on the visiting committee of the Peabody Museum at Harvard University.

In January, 1915, he was the official representative of the Smithsonian Institution at the inauguration of Doctor KleinSmid as president of the University of Arizona and had bestowed upon him by that institution the degree of LL. D. On the occasion of his seventieth birthday, November 14, 1920, a luncheon was given in his honor at the Smithsonian building, participated in by about 40 of his friends, and a specially bound volume of letters of congratulation was presented to him. His last public act was the presentation of a bust of Louis Agassiz to the Hall of Fame on behalf of the American Association for the Advancement of Science and an unnamed admirer of the great naturalist. This took place on May 10, 1928, Doctor Fewkes being the only pupil of Agassiz then living able to be present.

His publications include, besides the two papers on electricity already mentioned, nearly 70 contributions to invertebrate zoology, mainly the Medusae, Echinodermata, and Vermes, and about 200 contributions to ethnology and archeology.

Doctor Fewkes was possessed of a genial and confiding nature and an effervescent enthusiasm which drew people to him and made them readily communicative of any information they happened to have regarding new types of ruins, unique pottery, or mounds which had escaped scientific eyes, so that, from the quantity point of view, he was almost uniformly successful in his field expeditions. And in this way he made many openings for later workers, even though he did not exploit all the possibilities of an undertaking. For he was interested in variety of material, especially material of a novel character, rather than in associations of materials, and the extension of his work interfered with its intensiveness. However, his unaffected pleasure in a new variety of artifact or an exceptional pottery design was something that the average man could understand and through his talks to tourists and in the lecture hall, and through press interviews, he interested hundreds to whom a more rigorous student might have spoken in vain. In this way he created a "Pueblo consciousness" which drew other investigators to the field and provided popular support for their work, performing a similar service to that of Cushing at an earlier date on the side of ethnology. Thus the title "dean of American archeology" which, with advancing years, some of his admirers came to apply to him was not inappropriate. It was a term which his charm of manner set off to most excellent advantage, and he had a devoted circle of friends who will feel that his going has removed something peculiarly warm and winning from their lives.



GEORGE PERKINS MERRILL

# GEORGE PERKINS MERRILL (1854–1929)[1]

By CHARLES SCHUCHERT

[With 1 plate]

George Perkins Merrill was born May 31, 1854, at Auburn, Me., and died there suddenly on the morning of August 15, 1929. He was spending his vacation at his summer home on the Isle of Springs off the coast of Maine. On the afternoon of the 14th he left the island to look up a reported find of large beryl crystals at Albany, Me. That night he spent with his brother, Horace, at Auburn. Starting early the next morning for Albany, he was stricken with apoplexy in the railway station at Auburn while waiting for the train. As Miss Moodey writes:

> It seemed quite strange that he should have gone back to his birthplace and died there; it is also there that he is buried. The funeral services were held on Sunday the 18th in the Minot Church, where his grandfather preached.

Merrill's father, Lucius Merrill, a carpenter and cabinetmaker, was a descendant of Nathaniel Merrill, who settled in Newbury, Mass., in 1633, and who is stated to have been one of the Huguenot de Merles who were driven out of France at the time of the massacre of St. Bartholomew, the name "Merrill" being a corruption. His mother, Anne, was the daughter of the Rev. Elijah Jones, of the First Congregational Church at Minot, Me. There were seven children. He writes:

> The home being somewhat crowded, I lived for several summers with my grandfather in Minot, and after I had become of sufficient age to be of value, worked for three summers on the neighboring farm of my uncle. I was educated in the town schools of Auburn and the Lewiston Falls Academy, situated in Auburn, afterwards known as the Edward Little High School. I early became quite independent, at first doing small chores for the neighbors, then

[1] In the preparation of this memorial, the writer has had the advantage, through the kindness of Mrs. Merrill, of seeing an autobiographical sketch prepared by Doctor Merrill at the request of the National Academy of Sciences in April, 1924; and he is indebted for other information to Miss Margaret W. Moodey, assistant in the department of geology, United States National Museum. The writer's personal acquaintance with Doctor Merrill began in 1893 and covered 10 years of association with him in the United States National Museum and three years spent as a member of his family. It was kept alive after their paths diverged by correspondence and occasional contacts. Hence, the present tribute is not only to a scientific colleague, but to a highly valued friend. A more detailed sketch of Doctor Merrill, accompanied by a complete bibliography, will be found in the Bulletin of the Geological Society of America, vol. 42, 1931.

working with my father, when at school acting as janitor of the building, and in later years, from 18 to 21, working in the shoe factories. My education up to the time I was 21 was necessarily scrappy, but in the winter of 1876 I entered the University of Maine (then the small and struggling Maine State College), working my own way as in years previous and graduating in chemistry with the degree of B. S. in 1879. Later I received the honorary degrees of M. S. (1883) and Ph. D. (1889) from the same institution.

During the winter of 1876 I taught school at what is known as the Jackson district in Minot Center and during the vacations of the subsequent winters at East North Yarmouth, all in the State of Maine, receiving in the first instance $25 a month and board, and in the second, $30 a month and board as remuneration. I taught everything asked for—to students ranging from those who were sent to keep them from under their mother's feet to those who were as old and several sizes larger than I was myself. Along with the a, b, c's, I taught English, grammar, French, algebra, and geometry, and it was even suggested that I add singing as an extra course! Since I felt that a line should be drawn somewhere I drew it there.

Immediately after graduating in 1879 Merrill became assistant to Prof. W. O. Atwater in Wesleyan University at Middletown, Conn., working with him on the chemistry of foods. It was while here that he made the acquaintance of America's greatest pioneer in museum administration, Dr. G. Brown Goode, a graduate of that university and some time curator of its museum collections, but at this time in charge of the United States National Museum. They were attracted to each other at once and it was this meeting, together with an earlier recommendation, that had much to do with Merrill's subsequent appointment in the National Museum. In the winter of 1880–81 Merrill was connected with the Fisheries Bureau at Washington, D. C., and in the following July was transferred by Doctor Goode to the staff of the geological department of the National Museum as aid to Dr. George W. Hawes, who had in 1880 been appointed curator of geology. As we shall see, it was the latter who started Merrill on his geological career, and mainly in the line of petrology.

In the sketch above referred to, Merrill says that he must have been born with a fondness for natural history, but adds:

> If in my work there may have been any one controlling influence it must be attributed to the summers of my childhood which I spent with my [maternal] grandfather. He was a man of far more scholarly standing than the majority of clergymen in like situations. In the parlor of his house, on the mantel over the fireplace, I remember there stood a stack of narrow pine shelves on which were placed from time to time such objects as were sent to him by missionary friends from heathen lands and such "natural curiosities" as came to hand. Among these last were found a long-horned, adult form of the pine tree borer, *Monhammus confusor*, and a hideous lace-winged "helldiver," *Corydalis cornuta*. Later I myself added many insect forms, including the big luna-moth which was esteemed a great treasure. But amongst the inorganic forms there was a curved piece of stone, like a fragment of a saucer, or possibly the segment of a sphere. There was nothing remarkable about it had it not been that there rested in

it a small spherical pebble, the two resembling an iron-stone concretion familiar to geologists. I long afterwards learned that the two had had no connection whatever, someone having placed the pebble in the receptacle. It always excited my attention and I never failed to examine it when admitted to the room. . . . When the old household was broken up by death and removal, I secured that specimen as my share of the spoils, and to-day it rests on another mantel over the fireplace of the living room in my home at Washington.

Further information regarding these early influences appears in a letter dated October 20, 1921, wherein Merrill states that it was in particular the insect collection belonging to his grandfather that excited his enthusiasm (MS., 1924):

What more natural than that with these "as an example" I should myself begin collecting, and under judicious encouragement soon had my room at home a far more diversified curiosity shop than anything displayed at my grandfather's? This indiscriminate collecting I carried through my school and college days, and so succeeded in impressing one of my influential friends, all unintentionally, that years afterward he recommended me to the late G. Brown Goode of the Smithsonian Institution as a promising youth for appointment on his staff.

I do not know that I had any very decided views on what profession I wished to take when I entered college. I had thought of civil engineering but this was mainly because it was an out-of-door pursuit—as I understood it. It was not long, however, before I decided on chemistry and natural history as more to my taste, and to these I gave most of my attention. Prof. A. B. Aubert was then professor of chemistry and as it turned out I became his favorite pupil. I failed, however, to become a chemist, though I became a fair analyst. Our professor in natural history was C. H. Fernald. I became, too, one of his favorite students and acquired much information that helped me in my subsequent career. What I learned in geology was almost wholly my own; not a single field trip did we get, nor were we taught even the rudiments of field work. My first real geological trip was with Prof. William North Rice, with whom I visited the contact between the trap and Triassic sandstone at Meriden, Conn., while assistant at Middletown.

Merrill was married in November, 1883, to Sarah, daughter of Joseph R. Farrington of Portland, Me. She fell seriously ill in 1892, and the family had to be divided between Maine and Washington. These were hard and trying days for the Merrills. Mrs. Merrill died in 1894, leaving four children, Joseph Farrington, Anne Margaret, Mildred Hastings, and Ruth. In February, 1900, Merrill married Miss Katherine L. Yancey, of Virginia, by whom he had one daughter, Katherine Dorothy. During the years 1909 to 1913 Merrill himself had setbacks through illness, necessitating repeated visits to the hospital, but from this trouble he apparently recovered fully.

Physically, Merrill was 5 feet 10 inches in height, of sturdy build, with sandy hair and keen blue eyes. Alert and active, he was always occupied, spending most of his evenings reading, not only the scientific publications of the day, but the best literature as well; on his table invariably lay copies of the poems of Robert Burns, the

Rubaiyat of Omar Khayyam, and some volumes of Edwin Arlington Robinson; in fact, he was ever a lover of music and poetry. A typical "down East Yankee," he appeared on first acquaintance austere, reserved, and pessimistic, but to his many friends, though always critical, he showed a loyal and generous heart. Those who met him as host or at any social function found him unsurpassed in humor and in apt quotation.

Merrill's thought was rarely, if ever, speculative. As Farrington (1930) says, "He preferred to keep close to facts and allow time and accumulation of further data to furnish their interpretation," a tendency to which he himself bears witness when he states that he prefers in his daily work "to be always afloat in regard to opinions in geology." (1913a:67.)[2]

His ideals of what qualities a geologist should possess professionally may be read in his statement at the centenary of the birth of James D. Dana, whom he greatly admired. "A geologist," he says, "must be, first, a good observer; second, he must be sufficiently grounded in certain basal sciences to enable him to draw legitimate conclusions from what he observes; third, he must know what other workers have done and be able to utilize to advantage their work and conclusions; fourth, he must have staying power; fifth, if he is a great geologist he must possess a creative imagination and be master of both inductive and deductive methods of reasoning." (1913a: 64–65.)

Merrill was a Government officer in the United States National Museum for nearly a half century (1881–1929). His official and scientific career there will be presented under four headings, as follows:

I. As organizer of the department of geology in the National Museum.

II. As pioneer in the study of building stones and the processes of rock weathering.

III. As pioneer in the application of petrology to the study of meteorites.

IV. As pioneer historian of North American physical geology.

## MERRILL AS ORGANIZER OF THE DEPARTMENT OF GEOLOGY IN THE UNITED STATES NATIONAL MUSEUM

As previously stated, Merrill began his long and fruitful Washington career in the winter of 1880–81 as aide in the United States Fisheries Bureau. The following July he was transferred to the department of geology in the National Museum, which had started in 1880 in charge of Dr. G. W. Hawes, who died in 1882. The next

[2] This and subsequent references are to Merrill's bibliography as it will appear in the Bulletin of the Geological Society of America.

year Merrill was promoted to be acting curator in charge of the division of lithology and physical geology, working on the collection of building stones, and starting another one having to do with physical geology. In the annual report for 1884, he says that for whatever material the department possessed prior to 1882 it was largely indebted to the Centennial Exposition of 1876 held at Philadelphia, the Tenth Census, and the various national geological surveys. It was this material that he was then laboring to put into museum order. "The years immediately following the death of Hawes were full of hard work and much trial." In 1889 Merrill was promoted to full curatorship, and in 1897 to head curatorship in the newly organized department of geology, embracing the divisions: (1) Physical and chemical geology, with Merrill as curator; (2) mineralogy; and (3) stratigraphic paleontology. This appointment came to him while he was in St. Petersburg attending the International Geological Congress.

> This reorganization whereby the entire geological, mineralogical, and paleontological departments were placed under a single administrative head rendered possible, for the first time in the history of the museum, systematic and coordinate work in all divisions and at the same time permitted the writing of a consecutive report of progress . . . The collection up to that time had grown in a very irregular and spasmodic manner, the mineral collection being particularly poor and the meteorites hardly worthy of mention. By means of money appropriated to the museum for the purpose of taking part in the various expositions I had, however, succeeded in making the geological exhibits comprise something more than a collection of building stones and ores, by seizing the opportunity to build up exhibits along lines in which the museum was particularly weak. (MS. 1924.)

In Merrill's time there were 10 of these expositions.

As is well known, Merrill proved himself one of the most effective of museum exhibitors and husbanders of geologic materials. Under his care the department of geology in the National Museum grew from a small and insignificant beginning to one of the great collections of the world, and one which possibly is unexcelled.

Anyone who has held a curatorship in a large museum knows that most of his time goes into the husbanding of the collections in his charge, and caring for the daily work. This routine is greatly increased in a national museum since the Government feels obliged to answer, so far as it can, all questions asked of it by its citizens. Hence, as Merrill has said, "The curators are subject to a continual bombardment of letters containing queries covering a wide range of natural history topics, which are only too frequently of a trifling nature, dealing with matters which are curious but not important, but all of which require an answer." (MS. 1924.) On the other hand, "the care of the collections and installation of exhibits has always been considered the first duty of the departmental force. Research,

except in a few instances, has been secondary—to be carried on as time from these other duties permits. In addition specialists and interested visitors must naturally be shown all possible courtesies. Finally, label writing for the exhibition series requires the greatest care and a thorough knowledge of the subject described." (MS. 1929.) It is therefore only by the most careful husbanding of the curator's time that any research work can be accomplished at all, and most of it is done out of official hours. How well Merrill made use of his time and facilities is attested by his bibliography of nearly 200 titles, many of which are long papers and books. In addition, he wrote 47 annual reports of his department, and was a contributor of articles to at least six dictionaries and cyclopedias. Furthermore, in the years 1893 to 1916 he held the chair of geology and mineralogy in the Columbian (now George Washington) University and lectured several times each week during the college year to undergraduates, finally retiring on account of ill health. This teaching he likewise did after official hours. He also was lecturer in the Maryland Agricultural College in 1890–91.

Merrill's first geologic work had to do with the microstructure of building stones and their preparation for exhibition in the Museum. In 1883 appeared his first report as curator, in the course of which he states that he has in his keeping about 12,500 specimens, of which 3,862 were the just added building stones. These new and old collections occupied him for the next few years. He soon came to see that "the facts in regard to each and every specimen should be so placed on record that its identity can never again be lost, however often the administrative force of the department may be changed." This greatest of museum necessities he learned from the old collections then in his charge, which were largely valueless because of the loss of labels, or, worse, because labels had never been written.

In 1889 Merrill feels that his department in the Museum is in good condition, "having become fairly established." In the following year he is striving to apply the educational views of that born museum worker, Doctor Goode, then in charge of the National Museum, by making the geological exhibition series "a profusely illustrated textbook in which the objects themselves serve as illustrations, and the text, reduced to a minimum amount, is furnished by the labels." By 1891 his department has "at last emerged into a systematic series of collections, designed to show something regarding the earth's structure and history and the extent to which its resources are utilized by man." His section now had about 35,000 specimens, and that of mineralogy about 25,000 more.

After 1890 the Department of Geology grew especially rapidly and in 1897 there were about 60,000 items in its reserve collections.

At this time, even though all of Merrill's official time was taken up with official routine, he was in his happiest years, saying in 1901, "The department, as a whole, was never in better condition than it is to-day."

The greatest administrative task that came to Merrill was the moving of the geological collections from the old and very much crowded brick building to the far larger new granite one. A new arrangement of the exhibition collections had to be thought out, and decisions made regarding the type and arrangement of cases and their internal shelving. For this task Merrill had prepared himself while in Europe. He says:

> I made studies of Russian, English, and other European museums, with special reference to cases and methods of installation, acquiring information which became well-nigh invaluable to me in later years. (MS. 1924.)

The preparation for this move and the actual moving from the old into the new Museum between August, 1909, and June, 1910, was indeed a great labor for all concerned with the National Museum. Of the many consultations regarding it between the head curators (Holmes, Stejneger, and Merrill) he says:

> I believe our decisions in all these matters were the best and carried out with as great economy of funds as ever occurred under similar conditions anywhere. Our decisions for mahogany cases in place of steel were based upon architectural considerations, and I still consider the decision a wise one. Our exhibition halls certainly compare favorably with those of any natural history museum in the world.

The department of geology, starting in 1880 single-handed, had in 1929 grown to a staff of 15 paid or honorary curators and associates. In the way of material wealth the various sections then had in their reserve and exhibition collections the following number of specimens:

| | | |
|---|---|---|
| Section of geology | 93,044 | |
| Section of mineralogy and petrology | 132,279 | |
| | | 225,323 |
| Section of stratigraphic paleontology | | 1,765,600 |
| Section of vertebrate paleontology | | 24,497 |
| | | 2,015,420 |

Truly a remarkable growth!

### MERRILL AS PIONEER IN THE STUDY OF BUILDING STONES AND THE PROCESSES OF ROCK WEATHERING

Merrill appears to have been the first to make a systematic study of stone for building purposes, and in America the first also to study in detail the processes involved in rock weathering. "No material," he says, "has yet been found so well adapted to the nobler forms of architecture as stone." At the basis of this work lies the science of petrology, which deals with the microstructure and chemical nature

of rocks. It was along these lines that Merrill's greatest activity lay between 1881 and 1905, and during these years he published upwards of 80 papers and books, a total of 40 per cent of his entire bibliography.

The reason for Merrill's entering the field of petrology he tells as follows:

> My abrupt shift from chemistry to geology was due purely to a newly-made friendship with Doctor Hawes who was at that time one of the leading authorities on microscopic petrology, a branch of study then just coming into vogue. It was understood at the time of my accepting this position [in the National Museum] that, there being no university in America where this branch of geology could be studied, I should be assisted in taking it up by Doctor Hawes, but unfortunately, owing to his failing health, this part of the agreement was never carried out. At the time I became Doctor Hawes's assistant he had been appointed a special agent of the Tenth Census, in charge of the building-stone industry, his idea being to ascertain not merely the magnitude of the industry, but as well the petrographic characters of the materials. It was in the latter branch of the work that I was engaged. (MS. 1924.)

With the death of Hawes this study and the completion of the report fell to Merrill and he made good use of his opportunities, as the Tenth Census report shows. (1884b.) Before this study was completed Merrill further prepared himself in petrology at Johns Hopkins University, where the subject had been developed by Prof. George H. Williams.

Merrill's first duty in the Museum was the cutting of thin sections of the entire collection of some 4,000 samples of building stones that had been brought together from upward of 1,500 quarries in the United States, together with many from foreign countries—"the most systematic and complete collection of its kind in any museum in the world." Each specimen was examined under the microscope "in order not only to determine what the rock was, but also to ascertain if it contained any mineral constituents liable to unfavorable change on exposure to the weather." (1885a: 521.)

> As the Government hours were but from 9 a. m. to 4 p. m., I had opportunity to study and all encouragement in the way of use of the materials, and with Hawes' volume on the petrography of New Hampshire and Zirkel's report on the fortieth parallel rocks, together with the first edition of Rosenbusch's *Mikroskopische Physiographie*, I proceeded to equip myself as best I might.

The final report, by 21 authors, contained an introductory treatise by Hawes on micropetrology, followed by Merrill's account of the mineral nature and microstructure with illustrations, and was issued as a part of volume 10 (1884b: 15–29) of the publications of the Tenth Census.

> The 18 artotype reproductions of photographs taken through the microscope were the best that had thus far been reproduced.

This work on building stones naturally led to his first book, The Collection of Building and Ornamental Stones in the United States

National Museum. (1889c.) Merrill continued this work along the same lines on his own initiative, traveling and visiting quarries, examining old stone buildings whenever opportunity offered, and collecting data on weathering properties. Then he rewrote the book and published it as Stones for Building and Decoration. (1891b.) Of all Merrill's writings none had a wider circulation. It treats of the geographical distribution of building stones in the United States, their minerals, physical and chemical properties, and weathering qualities, and gives suggestions on their selection and testing. The book passed through three editions (1897b, 1903e) and was, as he says, "the first systematic work of its kind to appear in America, and I believe I may say was the chief instigator of the numerous investigations by State surveys along the same lines which were undertaken later." It established his reputation as an authority on the subject. Until the Bureau of Standards was established, the Government repeatedly called for Merrill's opinion on the stones to be used in its various buildings. The one building in which he took great interest was the Lincoln Memorial. The question of the ability of the so-called Yule Creek marble quarries in Gunnison County, Colo., to furnish material in quantity and in the unprecedented sizes needed for this memorial was favorably decided by him after a single visit to the place. "I may state, however," he adds, "that the selection of a marble for the structure was not mine. For our climate I would have preferred a light colored granite."

With regard to his work on rock weathering, he says:

> It is perhaps but natural that my attention having been called to the weathering of rocks when used for building purposes I should have turned my thoughts next to this particular phase of geology. The field was an inviting one and indeed the amount of superficial decomposed material overlying the rocks in the District of Columbia had early attracted my attention, since I had come from a glaciated region where like phenomena were almost wholly unknown. The results of my studies in this line were very favorably received. The main results were brought together in my treatise Rocks, Rock-weathering, and Soils. (1897b.) In the preparation of this volume, I had not only collected my own materials, made my own sections, but also many of the separations and chemical analyses, a detail which in the present condition of chemical science I should scarcely dare to attempt.

This book of Merrill's was unique and has been a source from which compilers of textbooks on agriculture have drawn their materials for many years. As Dr. Harvey W. Wiley said:

> Doctor Merrill is the most complete authority on soils. . . . He has given much to geology but has given much more to agriculture—how much the public will never know.

And in Europe, Farrington tells us, it is for this work on rocks and rock weathering that Merrill is best known.

Rocks disintegrate, alter, decompose, and dissolve, under all climates, but the decomposition is, Merrill says, most apparent under

moist and warm conditions. In rock weathering, "hydration is an important factor, the amount of water increasing rapidly as decomposition advances. In the earlier stages of degeneration it is doubtless the most important factor. There is, moreover, among the siliceous crystalline rocks, in every case a loss in silica, a greater proportional loss in lime, magnesia, and the alkalies, and a proportional increase in the amounts of alumina and sometimes of iron oxides, though the apparent gain may, in some cases, be due to the change in condition from ferrous to ferric oxide. As a whole, however, there is a very decided loss of materials. Among siliceous crystalline rocks, this loss, so far as shown by available analyses and calculations, rarely amounts to more than 60 per cent of the entire rock mass. Among calcareous rocks, on the other hand, it may, in extreme cases, amount to even 99 per cent." (1906a: 220.)

About Washington, Merrill had observed granitic rocks "so disintegrated at a depth of 80 feet from the present surface as to be readily removed by pick and shovel." About Atlanta, Ga., "the rocks are 'completely rotted' to a depth of 95 feet, while 'incipient decay' may reach to a depth of 300 feet." (1906a: 271.)

When F. P. Dewey in 1889 resigned his curatorship of economic geology in the National Museum, Merrill was asked to take over this work also. The task of overhauling and installing the nonmetallic economic collections early focussed his attention on these substances, resulting not only in a greatly improved exhibition collection but as well in a book, Guide to the Study of the Collections in the Section of Applied Geology: Nonmetallic Minerals. (1901c.) The popular demand for this shortly exceeded the supply and it was republished in modified form by John Wiley & Sons as The Nonmetallic Minerals. The purpose of this book is "to bring together the widely scattered notes and references relative to the occurrences and uses of sundry minerals of value other than as ores of metals." (1910b: iii.)

### MERRILL AS PIONEER IN THE APPLICATION OF PETROLOGY TO THE STUDY OF METEORITES

No geological problem interested Merrill more than that of meteorites, and of his entire bibliography of about 200 titles, no fewer than 80 have to do with these most interesting celestial bodies. The first three papers appeared in 1888 and the last one after his death, while the 20 years of greatest activity began with 1907.

Previous to 1897 the meteorites in the National Museum were considered as belonging to the mineralogical department, but in that year they were transferred to the division of geology and "recog-

nized as of petrographic rather than mineralogical interest and given an entity of their own." In 1880 the Museum had about 10 falls and finds, among which were the large irons of Tucson and Casas Grandes. In 1888 the number had increased to 128 specimens due to the active interest of F. W. Clarke, with 156 additional ones in the Shepard collection, which was placed on deposit in 1887 and became the property of the Museum in 1917. Most of the specimens in both collections were small. In 1902 there were, all told, 348 falls of which 143 were irons, and in 1916, 412 distinct falls and finds. Merrill alone has described 40 new falls. From Canyon Diablo the collection had 400 complete individuals weighing 2,200 pounds; and of the Holbrook, Ariz., find, over 600 complete individuals. (MS. 1929.) As Farrington has well said (1930), "In this as in all of his undertakings Merrill achieved remarkable success." Certainly he built for the National Museum one of the great meteorite collections of the world, probably the sixth one in numbers of falls and finds.

Meteorites, as defined by Merrill, are those "masses of metal and mineral matter which come to the earth from space in the form of falling bodies and which are commonly considered identical in nature with the meteors, or so-called 'shooting stars,' which on clear nights may often be seen darting rocket-like across the sky." (1916a: 1.) They are from regions outside our earth. "The most satisfactory theory would seem to be that they are fragments of comets which have gone to pieces." (1925c: 457.) A meteorite "furnishes tangible testimony of the nature of materials existing outside of our solar system, and affords, aside from the spectroscope, the only clue to the matter of which celestial bodies are composed." Truly they are chips of other worlds (Weltspäne), as the German Chladni said in 1794—"the remains of worlds gone to pieces." (1916a: 13.)

It is estimated that upward of 20,000,000 shooting stars strike the earth's atmosphere daily and are burnt into gas and dust, and the total weight of meteoric matter annually added to our earth has been estimated at 100,000 tons. Meteors are all small, "perhaps scarcely more than a grain in weight." Even iron meteorites up to 20 pounds may be wholly consumed in their flight through our atmosphere. The surface of the stony meteorites, as they fall on earth, consists of a black crust that is rarely more than a few millimeters thick. This crust is formed while the stone is falling through the atmosphere, burning at white to blue heat, and is eroded away about as fast as it is made. This black crust, according to Merrill, is "a more or less perfect glass." In iron meteorites the crust is thinnest, being an oxide of iron. (1916a: 21.)

Outside of the earth's atmosphere, meteorites move at high speeds, estimated to be around 25 to 50 miles per second. This speed through the air enveloping the earth brings about a pressure on the meteorite of about 10,000 pounds per square inch, and if the meteor is of friable stone it is crushed to fragments. "If the meteorite is of iron it may withstand the pressure, but in either case it catches fire and may be completely consumed. . . . It has been calculated that any iron meteorite must lose 90 per cent of its substance by being burned away in its passage" to earth. Not over three or four are found each year, and the number of all the iron and stony meteorites in the museums of the world is less than 1,000 and their total weight not over 200 tons. (1925.)

Meteorites on entering our atmosphere are greatly retarded and usually fall on the earth with speeds up to several miles per second. Some have been seen to fall so slowly as to rebound on striking ice, without either being broken, and others have buried themselves in the soil to depths of 5 feet and one went down to 11 feet. The stony meteorites range in size up to 660 pounds and the iron ones to 36.5 tons (Cape York, west Greenland). Of all the known meteorites about one-half have been seen to fall and have then been found (these are called "falls"); others, discovered without having been seen to fall, are labeled "finds." Of the falls only 10 are irons, and accordingly most of the metallic ones are finds. Usually a fall consists of a single specimen, but among the stones the individuals of a single fall number at times thousands and in two cases each fall yielded as many as 100,000 stones.

*Constitution of meteorites.*—The meteorites of celestial space show "so great a uniformity of material yet so individualized that one conversant therewith can tell almost at a glance whether celestial or terrestrial in origin." (1930: 47.)

"The elemental matter of meteorites is the same as that of the earth." In meteorites there are surely known 10 common and 18 rarer elements; 7 other elements have been reported but as yet these are not proved. "Though the elemental matter of meteorites may be the same as in terrestrial rocks, the form of combination is at times radically different and of a nature to indicate that they formed under conditions quite unlike those existing on the earth to-day, and particularly so with reference to the presence of free oxygen and moisture." (1916a: 1, 5.) One of the minerals known in meteorites is *merrillite*, first noted and described by Merrill, and named by Wherry in 1917 in honor of its discoverer. Farrington (1930) defines it as "a calcium sodium phosphate, differing in composition from any known terrestrial mineral."

"All known meteorites are composed of volcanic materials, and none has shown any traces of animal or vegetable life." Many have undergone metamorphism. "They are comparable with more or less compacted and altered masses of volcanic ash or tuff." Nor is there present anything in the nature of a true vein rock, a terrestrial sedimentary or a metamorphic or pumiceous one, "and nothing in content of silica, alumina, lime or alkalies corresponding to the granites." All meteorites "are of a basic nature, related closely to the basalts, pyroxenites, and peridotites among terrestrial forms." (1919a: 184; 1930: 39, 45.)

Merrill arranges the meteorites into "three somewhat ill-defined groups" as follows:

| | |
|---|---|
| Aerolites or stony meteorites. | Chondritic meteorites, consisting essentially of silicate minerals with minor amounts of the metallic alloys and sulphides. About 90 per cent of all known stony meteorites are chondritic. |
| Siderolites or stony-iron meteorites. | Consisting of an extremely variable network or sponge of metal, the interstices of which are occupied by the silicate minerals. |
| Siderites or iron meteorites. | Consisting essentially of an alloy of nickel-iron (5–25 per cent nickel) with iron phosphides and sulphides. Nearly or quite devoid of silicate material. |

*Chondritic meteorites.*—For what they teach, the most interesting meteorites are the stony ones, the aerolites. These chondritic meteorites have small spherical and oval grains known as chondrules (from the Greek word for grain) and composed of silicate constituents, "the formation of which affords one of the most interesting puzzles in connection with the origin of meteorites."

Mineralogically, the chondrules are composed chiefly of olivine or pyroxene. "Some are largely of an undifferentiated glass. Feldspars occur but rarely except in the form known as maskelynite. In addition are occasional inclosures of metal or metallic sulphides, chromite or other minor constituents." (1920d: 450.)

Merrill in 1916 thought that the chondrules might be looked on as the solidified molten drops of a "fiery rain" or a world-making mist. Later, however, after a study of all the thin sections of stony meteorites in the National Museum he changed this view, saying:

> In none of them do I find chondrules developed in the variety and perfection of forms existing in those meteorites which are plainly tuffaceous. This fact and others . . . have led me to regard the larger part if not all chondritic stones as originally tuffaceous and owing their more or less crystalline condition, where such exists, to heat and pressure in a nonoxidizing or even reducing atmosphere. (1920d: 462–463.)

*Meteor Crater.*—Probably the most remarkable phenomenon thought to be connected with the falling of meteorites is a crater-

like circular hole about 4,000 feet in diameter and 600 feet deep, known as Meteor Crater, situated 12 miles southeast of Canyon Diablo, Coconino County, Ariz. In the summer of 1907 Merrill was detailed by Secretary Walcott of the Smithsonian Institution to make a study of this so-called Coon Butte or Meteor Crater. Here he had the guidance of Mr. D. M. Barringer, a mining engineer who had been unsuccessfully exploiting the place in the hope of recovering the main mass of the meteorite.

Meteor Crater has a raised rim, which stands from 120 to 160 feet above a plain made of horizontal strata of Permian age. At the surface is the buff-colored arenaceous Kaibab limestone and beneath it the very porous, gray, highly siliceous Coconino sandstone, with a thickness greater than 400 feet. Ever since the great hole was found, geologists have been asking: Was it made by a blow-out from within, or is it due to an external impact of a stellar body?

The rim of the crater, according to Merrill (1908a), is composed of loose unconsolidated rock fragments of all sizes, from microscopic dust to blocks weighing thousands of tons. The crater walls "are composed of the crushed, broken, and bent strata of the limestone and sandstone forming the floor of the surrounding plain, and which dip away from it in all directions." The dips vary between 10° and 80°. "Perhaps the most significant feature of the ejectamenta is the occurrence of enormous masses of the sandstone which have undergone a partial metamorphism through crushing and heat. . . . This material must have come from a depth of at least 300 feet below the original surface." There is also a vast amount of a chalky white siliceous rock-flour, the shattered grains of the gray sandstone. Outside of the rim "are many low, rounded, moraine-like deposits composed of the same material as the rim, but for the most part in a comparatively fine state of disaggregation."

The deepest part of the crater is about 440 feet below the level of the plain. Much loose material has been washed into the pit, hence the original depth must have been considerably greater. Bore holes put down to 1,100 feet reveal, below the floor of the crater, crushed rock (as a rule rock-flour) down to 620 feet, and then follows undisturbed bed rock—a gray sandstone that is not metamorphosed.

The Canyon Diablo iron meteorites found on the rim and the adjacent plains are "the most interesting and instructive of known meteorites," containing small black and white diamonds. At least 20 tons of these irons are known to have been gathered over several

square miles of the ground about the crater; in number they run into the thousands and in weight from 1 gram up to 1,013 pounds.

Merrill concludes from the shape, size, and ejected material of Meteor Crater that the evidence points strongly "to an origin by impact. It is difficult, if not impossible, to conceive of the smashing and metamorphism of the sandstone on any other ground. The sand grains are crushed in a manner that could be brought about only by some sudden shock. . . . The fused quartz indicates great heat. . . . The slightly disturbed and unchanged condition of the deeper-lying sandstones seems to prove the superficial character of the phenomena." The higher strata dip downward "as though forced out of position by some power acting from above." The infall of meteoritic material "seems worthy of serious consideration." (1908a: 489–490.)

*The place of meteorites in the solar system.*—Students of meteorites are now all agreed that they are celestial bodies fallen on our earth. Farrington is inclined to regard the meteorites as "portions of extraterrestrial bodies," in other words, as "fragments of some pre-existing body rather than independent celestial bodies." (Meteorites, their Structure, Composition, and Terrestrial Relations, 1915: 211.)

According to T. C. Chamberlin, the meteorites are all independent members of the solar family, originating out of the sun when it was interfered with by a far larger intruding star. This approach caused mother sun to give birth to her very numerous family of planets and their satellites, to the erratic comets, to the meteorites, and to the chondrules to which alone Chamberlin restricts the popular term "shooting stars." The careful student must clearly keep in mind that Chamberlin regards planetesimals and chondrules as the world-making stuff born of the sun. The planetesimals "revolve concurrently in a narrow disk and are thereby fitted to collect into planets"; while the widely sweeping chondrules are not so restricted, and gathering into swarms remain discrete and compose the heads of the very erratic comets; the other chondrules, revolving close about the sun, gather into the meteorites and are from time to time more or less completely fused or metamorphosed. (The Two Solar Families, 1928.)

## MERRILL AS PIONEER HISTORIAN OF NORTH AMERICAN PHYSICAL GEOLOGY

It was but natural that, in his position as head curator in the United States National Museum, Merrill should have to know something of the connections, education, and career of his colleagues and his predecessors, and in his administrative work it was often necessary for him to look up the records of the early Government surveys

with a view to ascertaining the final disposition of their collections. Having this information, he began lecturing to his students at Columbian (now George Washington) University about these surveys and the older generation of geologists. This led him to devote "odd moments" in his official life to the study of the rise and progress of American geology, with the result that he became the historian of our science previous to the present century. He wrote memorials of James D. Dana, John W. Powell, Joseph P. Iddings, George F. Becker, George W. Hawes, Carl L. Rominger, Edward T. Cox, and W. S. Yeates; and brief sketches of 196 American geologists were combined to form his Contributions to the History of American Geology (1906e), which was the first book of its kind. In addition, he prepared many shorter sketches for the Dictionary of American Biography, now in process of publication.

From the "Contributions" we learn that the pioneers of American geology "had received little or no preliminary training along these special lines, and had access to but few books. The information with which the geologist of to-day begins his career did not then exist, and an effort has here been made to show by what years of toil each new fact has been unearthed, cleansed of the débris which obscured its outlines, and treasured up in such form that it is now possible for the student, in a few short years, to encompass the garnerings of a century. Nor must it be thought that in touching upon sundry disputes, quarrels, and petty jealousies it has been done with an idea of belittling the individual in any way. Indeed, a truly able man is not belittled by his weaknesses. To appreciate his strength we need to know his weakness. These were but men, and we, who are weakly human, like to recognize in them human traits—like to learn of their errors in judgment and wordy warfares." (191–192.)

In 1924, the Yale University Press brought out this book, very largely rewritten, under the title "The First One Hundred Years of American Geology." Schuchert in reviewing it said:

> It is a history of the growth of geology in America in all of its physical aspects. Beginning with 1785, it goes on to the closing years of the past century—a review of the gradual development of the science in this country through 100 years. . . . It is an impressive volume.

"Early American geology," Merrill says, "was preeminently a science of observation and deduction. Information on which to base theory and hypothesis was not available—indeed, did not exist. With the accumulation of recorded observations it became possible to carry conclusions beyond the point of mere observation, and the inductive method was evolved. Well toward the close of the period . . . synthetic methods of research were introduced by which the

attempt is being made to discover by actual experiment in the laboratory the correctness or falsity of deduction or of inductive reasoning." (1924, preface.)

Merrill also wrote Contributions to a History of American State Geological and Natural History Surveys. (1920a.)

In the course of his historical research, Merrill accumulated portraits and autograph letters, not only of most of the American pioneers, but of a great many of the later American geologists as well, and this very valuable collection has now been given to the Museum in which he labored so long.

## MERRILL'S HONORS

Merrill was elected into the National Academy of Sciences in 1922, thus receiving the greatest honor that can come to a man of science in America; and in that same year he was awarded the J. Lawrence Smith gold medal of the academy for his work on meteorites. He was a member of the American Philosophical Society, the Academy of Natural Sciences of Philadelphia, the Washington Academy of Sciences, the Geological Society of America (vice president 1920), the Geological Society of Washington (president 1906–07), and the Maryland Academy of Sciences; and a corresponding member of the American Institute of Architects and several other organizations. His fraternal affiliations were with Phi Gamma Delta and Phi Kappa Phi, and he was a member of Phi Beta Kappa and Sigma Gamma Epsilon.

Of honorary degrees, he held an M. S. and a Ph. D. from the University of Maine, and a Sc. D. from George Washington University.

A very great honor, and certainly a most enjoyable one, came to Doctor Merrill on the evening of his seventy-fifth birthday, when he was given a testimonial dinner by his many friends and colleagues from scientific circles. At this love feast many nice things were said of him and of his scientific career, and out of the report of the dinner in Science (August 2, 1929: 122–123) the following is gleaned:

> [For nearly half a century Merrill had been connected with the Smithsonian Institution.] During this time Doctor Merrill has won admiration and high esteem from his many friends and acquaintances in scientific and social spheres. His career is indicated by his versatility. He is a teacher, a critic, a public speaker, an executive, and a scientist. During his long and active life, Doctor Merrill has done much for the advancement of science, among his many achievements being several works which stand out as monuments, namely, Stones for Building and Decoration, Rock-weathering and Soils, The First One Hundred Years of American Geology, and his many highly enlightening works on meteorites, for which in 1922 he was awarded the J. Lawrence Smith medal by the National Academy of Sciences.

After the dinner there was presented to Merrill a bound volume of more than 200 letters of congratulation and esteem, from his friends and colleagues of this and foreign countries. Concluding his thanks with lines expressive of a hope based upon T. B. Brown's well-known poem, Merrill said:

"I stand upon the summit of my years,"
So may it ever be,
Not bowed beneath their weight
With feet firm planted
And soul undaunted
I'll stand and contemplate
What time has wrought
And tremble not
For what was, is, or is to be,
I'll stand upon the summit of my years.

# INDEX

## A


Page

Abbot, Dr. Charles G., secretary of the Institution---- III, XII, 10, 13, 18, 24, 45, 48, 53, 71, 83, 102, 113, 114, 122, 125, 129, 140, 146, 159, 160, 161
Abbot, Mrs. Frederic V ---- 129
Abbott, Dr. W. L---- 4, 28, 32
Aboriginal decorative art in America based on specimens in the United States National Museum, Aspects of (Krieger)---- 519
Acheson memorabilia, Edward Goodrich---- 30
Acheson Oildag Co---- 30
Acker, Mr---- 60
Adams, Charles Francis, Secretary of the Navy (member of the Institution)---- XI
Adams, Herbert---- 45
Age of the human race in the light of geology, The (Richarz)---- 451
Agriculture, Secretary of (member of the Institution)---- XI
Agriculture, United States Department of---- 28, 115
Ahmet Mouhtar Bey, Turkish Ambassador to the United States---- 31
Akeley, Carl---- 23
Alaska Game Commission---- 85
Aldrich, Dr. J. M---- VII, 36, 37
Aldrich, Loyal B., assistant director, Astrophysical Observatory---- XII, 113
Allotments for printing---- 146
American Association for the Advancement of Science---- 128
American Association of Museums---- 128
American Federation of Arts---- 49
American Historical Association, report---- 141, 145
American Historical Society---- 129
American Hungarian Foundation---- 49
American Museum of Natural History---- 131
American Negro artists, paintings by---- 49
American Numismatic Association---- 31
American Propeller Co---- 31
Animal industry, Bureau of, Pathological Division---- 89
Animals in the collection June 30, 1930, National Zoological Park---- 90
Annals of the Astrophysical Observatory---- 141
Anthropological Society of Washington---- 128
Applied entomology in the United States, The rise of (Howard)---- 387
Appropriations, table of, for past 10 years---- 157
Archaeological Institute of America---- 128
Art, aboriginal decorative, in America, Aspects of, based on specimens in the United States National Museum (Krieger)---- 519
Art works received during the year, National Gallery of Art---- 49
Arthur, James---- 162
Assistant secretary of the Institution---- XI, 13, 36, 44, 129, 159, 160

Page
Astrophysical Observatory ..... XII, 1, 7, 12, 20
annals ..... 141
field stations ..... 112
library ..... 126, 133
personnel ..... 113
plant and objects ..... 103
report ..... 103
staff ..... XII
work at Washington ..... 103
atmospheric ozone ..... 104
reduction of observations ..... 104
solar variation and temperature changes ..... 107
Atchison, Joseph Anthony ..... 51
Attorney General (member of the Institution) ..... XI
Autogiro, The: its characteristics and accomplishments (Pitcairn) ..... 265
Avery fund ..... 4

B

Babcock, H. D. (Beyond the red in the spectrum) ..... 165
Babcock & Wilcox Co ..... 31
Bacon fund, Virginia Purdy ..... 4, 150, 155
Bacon traveling scholarship, Walter Rathbone ..... 15, 29, 34
Badé, William Frederic (The Tell en-Nasbeh excavations of 1929—a preliminary report) ..... 483
Baird fund, Lucy H ..... 4, 150, 155
Baker, Arthur Benoni, assistant director, National Zoological Park ..... 23, 84
Balance sheet of the Smithsonian Institution, June 30, 1930 ..... 155
Bancroft, B. B ..... 30
Bartsch, Dr. Paul ..... XII, 13, 29, 34, 84
Bassler, Dr. Ray S ..... XI, XII, 38, 43, 146
Beam expedition, third, National Geographic Society ..... 33
Beedy, Hon. Carroll L., M. C ..... 50
Bell, Dr. Alexander Graham ..... 134
Belote, Theodore T ..... XII
Benjamin, Foster H ..... 85
Benjamin, Dr. Marcus, editor, National Museum ..... XII, 129, 144, 146
Bennett, Miss Alva L ..... 44
Bent, A. C ..... 17, 29
Berry, Prof. E. W ..... 30, 42
Beyond the red in the spectrum (Babcock) ..... 165
Biological Survey, United States ..... 85
Bishop, Dr. Carl Whiting, assistant curator, Freer Gallery of Art ..... XII, 60
Blakeslee, Albert F. (Extra chromosomes, a source of variation in the Jimson weed) ..... 431
Bobzien, Lieut. Edwin B., United States Army ..... 33, 68
Boehmer, Lucy C. (Mrs. George H.) ..... 68
Bogoras, W. G. (Elements of the culture of the circumpolar zone) ..... 465
Bond, Mrs. A. M ..... 113
Borie, Charles L., jr ..... 45
Boss, Norman H ..... 30, 39, 44
Brackett, Dr. Frederick S ..... XII, 12
Brackett, F. S., and Earl S. Johnston (New researches on the effect of light waves on the growth of plants) ..... 255

Page
Brandes, Dr. E. W---- 28
British Museum---- 129
British School of Archaeology in Jerusalem---- 129
Brookings, Robert S. (regent)---- xi, 3, 161
Brown, Walter F., Postmaster General (member of the Institution)---- xi
Bryant, Herbert S., chief of correspondence and documents, National Museum---- 40
Bryson, Miss Charlotte Arnold H---- 50
Buildings and equipment, National Museum---- 40
Bundy, John, superintendent, Freer Gallery of Art---- xii
Bushnell, David I., jr---- 68
Butler, C. P---- 113
Byrd, Admiral Richard Evelyn, United States Navy---- 2, 7, 8, 162

C

Canfield collection fund---- 4, 150, 155
Canu, Dr. Ferdinand---- 38
Capital Audit Co---- 158
Carnegie Institution of Washington---- 30, 39, 137
Carnochan, Fred G---- 84
Carr, Miss Virginia---- 42
Casey fund, Thomas L---- 4, 150, 155
Casey, Mrs. Laura Welsh---- 4
Cash balances, receipts, and disbursements during the fiscal year---- 152
Catalogue of Scientific Literature, International, United States Regional Bureau of the---- xii, 1, 7
report---- 123
Caudell, A. N---- 129
Chamberlain fund, Frances Lea---- 4, 17, 30, 150, 155
Chambers, Moreau B---- 32
Chancellor of the Institution---- 21, 161
Chanute, Octave---- 134
Chapman, Charles S---- 48
Chapman, Frank M. (The nesting habits of Wagler's oropendola on Barro Colorado Island)---- 347
Chase, Mrs. Agnes---- 37
Chemistry, Modern concepts in physics and their relation to (Langmuir)---- 219
Chicago University---- 138
Chief clerk of the Institution and administrative assistant to the Secretary---- xi
Chief Justice of the United States (chancellor and member of the Institution)---- xi, 2, 3, 21
Child, Edwin B---- 18
portraits by---- 49
Chromosomes, Extra, a source of variations in the Jimson weed (Blakeslee)---- 431
Chrysler fund, Walter P---- 85
Circumpolar zone, Elements of the culture of the (Borgoras)---- 465
Clancy, Michael J---- 129
Clark, Austin H---- xii, 117, 129
Clark, Dr. C. U---- 2, 8, 9
Clark, Leland B---- xii, 118
Clark, Miss May S---- 71
Clarke, Dr. Frank W---- xii
Cloud, Frisk---- 67

Page
Coast and Geodetic Survey, United States 31
Cole, Dr. Fay-Cooper 41
Collections, National Museum 27
anthropology 28
arts and industries 30
biology 28
geology 29
history 31
Collins, Henry B., jr 13, 17, 28, 32, 44
Commerce, Secretary of (member of the Institution) XI
Concilium Bibliographicum cards 138
Coolidge, Mrs. Calvin 31
Coolidge, Harold S., jr 85
Coomaraswamy, Dr. A. K 57, 59, 60
Copying paintings, National Gallery of Art 52
Corbin, W. L., librarian of the Institution XI, 58, 140
Corliss, Miss Mary 129
Coville, Dr. Frederick V XII
Crown Agents of the Colonies 128
Culture of the Circumpolar Zone, Elements of the (Borgoras) 465
Cumming, Mrs. Alistair Gordon 51
Cumming, Surg. Gen. H. S 42
Curators of the Institution XII
Curran, Charles P 48
Curtis, Charles, Vice President of the United States (member and regent of the Institution) XI, 3, 160
Curtiss, Glen H 7
Cyrogenic Laboratory at Leiden, director of 11

D

Daughters of the American Revolution, National Society, Report of the 145
Davenport, Dr. Charles B 42
(The mechanism of organic evolution) 417
David, Abbé Armand 34
Davis, James John, Secretary of Labor (member of the Institution) XI
Dawes, Ambassador Charles G 2, 8, 159
De Broglie, Louis (Waves and corpuscles in modern physics) 243
Decora, Paul 67
De Freygang, M 84
Delano, Frederic A. (regent) XI, 3, 158, 159, 160, 161
Denmark, Clayton R XII
Dennis, W. J 37
Densmore, Frances 19, 66, 67
Department of Agriculture, Ottawa, Canada 131
Director of National Zoological Park XII, 102, 146
Distributions, National Gallery of Art 51
Dobson, Dr. G. M. B 104
Dorsey, Harry W., chief clerk of the Institution and administrative assistant to the secretary XI
Dorsey, Nicholas W., treasurer and disbursing agent of the Institution XI, XII
Douglass, Dr. A. E 33
Duncan, George S 129
Dykaar, Moses Wainer 50, 51

## E


Page

Eastman Kodak Co. 31
Editors of the Institution and branches. xi, xii, 68, 129, 144, 145, 146
Edwards, Mrs. R. W. 60
Egberts, William H. 44
Eickemeyer, Rudolph. 17
  gift. 30
Eiffel, Gustave. 7
Ellsworth, Lincoln. 129
Endowment fund, Smithsonian. 4, 149
Entomology, applied, The rise of, in the United States (Howard). 387
Ethnological and archeological investigations, cooperative. 13
Ethnology, Bureau of American. 1, 7, 14, 19
  chief. xii, 19, 71, 146
  collections. 70
  distribution of publications. 69
  editorial work and publications. 68, 141, 145
  illustrations. 69
  library. 70, 126, 133
  report. 61
  special researches. 66
  staff. xii
European archives, researches in. 8
Events of the year, National Gallery of Art. 46
Evolution, organic, The mechanism of (Davenport). 417
Exchange service, International. 1, 7, 19, 27
  foreign depositories of governmental documents. 75
  foreign exchange agencies. 81
  interparliamentary exchange of the official journal. 78
  report. 72
  staff. xii
Expenditures for researches in pure science, explorations, care, increase and study of collections, etc. 154
Explorations and field work. 12
  National Museum. 32


## F


Far Eastern Archaeological Society. 129
Fewkes, Dr. J. Walter. 44
Fewkes, Jesse Walter (Swanton and Roberts). 609
Field work, Freer Gallery of Art. 60
Finances of the Institution. 3
First rains and their geological significance, The (Hadding). 285
Fish poisons in South America, The use of (Killip and Smith). 401
Fisher, Dr. A. K. 35, 36
Fixed Nitrogen Laboratory, United States Department of Agriculture. 12, 115, 121
Food plant of the Southwest, A rare parasitic (Thackery and Gilman). 409
Forbes, Miss Leila G., assistant librarian. xii, 44, 126
Forbes, V. S. (The moon and radioactivity). 207
Ford, James A. 32
Foreign depositories of governmental documents. 75
Foreign exchange agencies. 81
Fort Ticonderoga Museum. 129

Page
Foshag, Dr. W. F. xii, 38, 43
Fowle, Frederick E., jr. xii, 104, 113
Fox, Mrs. Charles J. 50
Fraser, James E. 45
Freer, Charles L. 150
Freer Gallery of Art. 1, 4, 139
attendance. 59
building. 59
field work. 60
fund. 150
library. 58, 126, 135, 137
report. 54
reproductions and pamphlets. 58
staff. xii
Freund, J. Loren. 42
Frick, Childs. 4, 39
Friedmann, Dr. Herbert. xii, 44
Froiland, A. G. 113
Furniture, Ancient seating, in the collections of the United States National Museum (Hough). 511
Furscott, Miss Daisy (Mrs. Carl W. Bishop). 60

G

Gaburri, Mme. Annita. 50
Garber, P. E. 129
Gellatly, John. 45
art collection. 7
Geographic Board, United States. 66
Geological Survey, United States. 137
Geology, The age of the human race in the light of (Richarz). 451
Geophysical Laboratory. 128
Georgii, Prof. Dr. Walter (10 years' gliding and soaring in Germany). 273
Gest, J. H. 45
Gidley, Dr. J. H. 30, 39, 40, 129
Gilbert, Chester G. xii
Gill, De Lancey, illustrator, Bureau of American Ethnology. xii, 69
Gilman, M. French, Frank A. Thackery and (A rare parasitic food plant of the Southwest). 409
Gilmore, Dr. Charles W. xii, 17, 30, 39, 40
Glaciation, Weather and (Reeds). 295
Gliding and soaring in Germany, 10 years' (Georgii). 273
Goddard, Dr. R. H. 2
rocket experiments of. 9, 10
Goldsborough, Edmund K. 51
Goldsborough, Mrs. Mary F. C. 51
Goldsmith, James S., superintendent of buildings and labor, National Museum. xii
Good, James Wilson, Secretary of War. 43
Governmentally supported branches. 16
Graham, Rev. D. C. 17, 28, 29, 34
Grant, W. Oliver. 113
Gray, Carl C., and H. F. Hagen (The eighth wonder: The Holland Vehicular Tunnel). 577

Page
Greeley, F. A. 113
Grock, Mrs. Florence L. 44
Guest, Grace Dunham, assistant curator, Freer Gallery of Art. XII
Guggenheim, Simon. 2, 10
Gunnell, Leonard C. XII, 125

H

Habel fund. 4
Hachenberg fund. 4
Hadding, Assar (The first rains and their geological significance). 285
Hagen, H. F., Carl C. Gray and (The eighth wonder: The Holland Vehicular Tunnel). 577
Hallson, O. 85
Hanna, Col. H. B. 57
Harmon Foundation of New York. 49
Harriman Alaska Expedition, report. 141
Harrington, John P. XII, 19, 63, 64
Harvard Mineralogical Museum. 38
Harvard University. 4, 138
Haweis, Stephen. 84, 89
Hay, Dr. O. P. 129
Hayden, Senator Carl. 33, 68
Helsley, Mrs. R. W. 60
Henderson, Edward P. 43
Henry fund. 4
Hewitt, John N. B. XII, 19, 65, 66
Hicks, Mrs. Frederick C. 50
Hill, Miss Christabel E. 60
Hill, James H., property clerk of the Institution. XI
Historiographical Institute, Tokyo, Japan. 16, 128
Hitchcock, Dr. A. S. 37
Hodgkins fund, general. 4, 155
Hodgkins fund, specific. 4, 150
Hoffman, Dr. William W. 34
Holland Vehicular Tunnel, the: The eighth wonder (Gray and Hagen). 577
Holmes, Dr. William H., director, National Gallery of Art. XII, 18, 45, 53, 129, 135
Holt, Ernest G. 17, 29, 36
Hoover, Herbert, President of the United States. XI
Hoover, Mrs. Herbert. 51
Hoover, W. H. 113, 119
Hough, Dr. Walter. XI, XII
(Ancient seating furniture in the collections of the United States National Museum). 519
Howard, Dr. Leland O. XII
(Man and insects). 395
(The rise of applied entomology in the United States). 387
Hrdlička, Dr. Aleš. XII, 13, 17, 28, 34, 42, 129
Hughes, Charles Evans, Chief Justice of the United States (chancellor and member of the Institution). XI, 159, 161
Hughes fund, Bruce. 4, 28, 150, 155
Hulitar, Mme. Bronislava De Brissac. 50
Human race, The age of, in the light of geology (Richarz). 451
Hungarian artists, paintings, sculptures, etc., by contemporary. 49

Page
Hungarian National Council of Fine Arts ..... 49
Hurley, Patrick J., Secretary of War (member of the Institution) ..... XI
Hutchings, DeWitt V ..... 50
Hyde, Arthur M., Secretary of Agriculture (member of the Institution) ..... XI
Hygienic Laboratory ..... 128

I

Insects, Man and (Howard) ..... 395
Interior, Secretary of the (member of the Institution) ..... XI
International Catalogue of Scientific Literature, United States Regional Bureau, of the ..... XII, 1, 7, 21, 128
report ..... 123
International Exchange Service ..... 1, 7, 19, 127
foreign depositories of governmental documents ..... 75
foreign exchange agencies ..... 81
interparliamentary exchange of the official journal ..... 78
report ..... 72
staff ..... XII
Interparliamentary exchange of the official journal ..... 78
Investments, classification of ..... 151
Ipsen, Ernest L ..... 48
Isham, Charles S ..... 17, 28

J

Jay, Mrs. John ..... 129
Jimson weed, Extra chromosomes a source of variations in the (Blakeslee) ..... 431
Johnson, Representative Albert (regent) ..... XI, 161
Johnson, Mrs. M. D. (Denoyer) ..... 113
Johnston, Mrs. Charles H. L. (Birdie Abbott Johnston) ..... 52
Johnston, Dr. Earl S ..... XII, 117, 161
F. S. Brackett and (New researches on the effect of light waves on the growth of plants) ..... 255
Judd, Neil M ..... XII, 33, 42, 65, 68, 129

K

Kalmbach, E. R ..... 85
Karolik, Mr. and Mrs. Maxim ..... 51
Keesom, Prof. Dr. W. H ..... 11
Kellers, Dr. H. C., United States Navy ..... 29, 36, 85
Kellogg, Dr. Remington ..... 30, 39, 40
Kelly-Roosevelt expedition ..... 85
Kidder, Dr. A. V ..... 61
Killip, Ellsworth P ..... XII, 13, 29, 37
and Albert C. Smith (The use of fish poisons in South America) ..... 401
Kinoshita, Y ..... 60
Knowles, William A., property clerk, National Museum ..... XII
Kramer, A ..... 113, 120
Kress, Samuel ..... 85
Krieger, Herbert W ..... XII, 13, 17, 28, 32, 44
(Aspects of aboriginal decorative art in America based on specimens in the United States National Museum) ..... 519

## L


Page

Labor, Secretary of (member of the Institution) ..... xi
Lacy, Miss Ethel A. L ..... 44, 126
LaFlesche, Dr. Francis ..... 19, 66, 71
Lamont, Robert P., Secretary of Commerce (member of the Institution) ..... xi
Langhorne collection ..... 45
Langhorne, Mrs. Marshall ..... 51
Langley aeronautical library ..... 15, 16, 126, 134
Langley gold medal for aerodromics ..... 7, 160, 162
  Award of, to Charles Matthews Manly and to Commander Richard Evelyn Byrd, United States Navy ..... 2, 7
Langmuir, Irving (Modern concepts in physics and their relation to chemistry) ..... 219
Laughlin, Irwin B. (regent) ..... xi, 3
Leary, Ella, librarian, Bureau of American Ethnology ..... xii
Leonard, E. C ..... 13
Lewton, Dr. Frederick L ..... xii
Li, Dr. Chi ..... 60
Libraries of the Institution and branches ..... 1, 15, 52, 58
  report ..... 126
  staff ..... 126
  summary of accessions ..... 136
Library of Congress ..... 15, 16, 59, 78, 126, 128, 131, 133, 134, 136, 137, 138
  Smithsonian deposit in ..... 130
Liddel, Urner ..... 12, 121
Light waves, effect of, on the growth of plants, new researches on (Brackett and Johnston) ..... 255
Lindbergh, Col. Charles A ..... 2, 7, 10
Loans accepted by the [National] Gallery [of Art] ..... 50
Loans returned to the [National] Gallery [of Art] ..... 51
Lodge, John Ellerton, curator, Freer Gallery of Art ..... xii, 60
Low-temperature researches ..... 11
Lucas, A. F. G ..... 128
Lucas, Albert P ..... 48
Luce, Representative Robert (regent) ..... xi, 3, 159, 160, 161


## M


MacCallum, Dr. G. A ..... 29
MacCurdy, George Grant (Recent progress in the field of Old World prehistory) ..... 495
MacMillan, Sir Donald ..... 24
Man and insects (Howard) ..... 395
Manly, Charles Matthews ..... 7, 8, 162
Mann, Dr. William M., director, National Zoological Park ..... xii, 102, 146
Marine Biological Laboratory at Woods Hole ..... 138
Marsden, Miss M ..... 113
Marshall Jones Co ..... 128
Maryland Geological Survey ..... 40
Maryland, University of ..... 12, 117, 122
Mather, Frank J., jr ..... 45
Maxon, Dr. William R ..... xii, 29
Maynard, Ross H ..... 129
McCormick, Leander James ..... 31

Page
McCormick, Robert Hall ... 31
McGuire, Miss Mary ... 17, 31
McKim, Miss Frances Gertrude ... 42
McKinley, President ... 22
Means, James ... 134
Meetings and receptions, National Museum ... 41
Melchers, Gari ... 45, 48
Mellon, Andrew W., Secretary of the Treasury (member of the Institution) ... XI
Merriam, Dr. John C. (regent) ... XI, 3, 158, 159, 161
Merrill, Dr. George P ... 22, 42, 44
Merrill, George Perkins (1854–1929) (Schuchert) ... 617
Meschter, Wayne C ... 129
Michelson, Dr. Truman ... XII, 19, 62
Miller, Gerrit S., jr ... XII, 129
Minneapolis Public Library ... 29
Mint, Bureau of the, United States Treasury Department ... 31
Mississippi Department of Archives and History ... 32
Missouri Historical Society ... 4
Mitchell, William D., Attorney General (member of the Institution) ... XI
Mitman, Carl W ... XII
Monegar, George ... 67
Moon and radioactivity, The (Forbes) ... 207
Moore, A. F ... 113
Moore, Representative Walton R. (regent) ... XI, 3, 158, 159, 160, 161
Moraes, Dr. L. J ... 38
Morrow, Dwight W. (regent) ... XI, 3, 159
Muhlhofer, Elizabeth ... 51
Munroe, Helen ... 69
Myer fund, Catherine Walden ... 4, 150, 155

N

National Academy of Design ... 18
Council of the ... 46, 48
National Academy of Sciences ... 4
National Aeronautic Association ... 16
National Gallery of Art ... XII, 1, 7, 17
art works received during the year ... 49
commission ... 18, 45, 49
report ... 160, 161
copying paintings ... 52
director ... XII, 18, 45, 53, 129, 135
distributions ... 51
events of the year ... 46
Henry Ward Ranger fund purchases ... 51
library ... 52, 126, 128, 135
loans returned to the Gallery ... 51
publications ... 52, 141
report ... 45
special exhibitions held in the Gallery ... 48
National Geographic Society ... 17, 33, 36
National Herbarium, United States, Contributions from ... 141, 144

Page
National Museum ..... 1, 7, 16
buildings and equipment ..... 40
collections ..... 27
curators ..... XII
explorations and field work ..... 40
library ..... 15, 16, 126, 128, 131
meetings and receptions ..... 41
Natural History Building, additions to ..... 8, 26
appropriations for wings on ..... 1, 16
publications ..... 14, 141, 144
report ..... 25
staff ..... XII
visitors ..... 43
National Zoological Park ..... 1, 7, 20
accessions ..... 84
animals in the collection June 30, 1930 ..... 90
director ..... XII, 102, 146
donors (list of) ..... 85
improvements ..... 100
needs of the zoo ..... 101
removals ..... 89
report ..... 84
staff ..... XII
visitors ..... 99
Natural History Society of Northumberland, Durham, and Newcastle-upon-Tyne ..... 129
Naval Observatory, United States ..... 138
Naval Solar Eclipse Expedition ..... 29, 36
Navy, Secretary of the (member of the Institution) ..... XI
Necrology ..... 21
Nesting habits of Wagler's oropendola on Barro Colorado Island (Chapman) ..... 347
New York Botanical Garden ..... 37, 131
Newton, Representative Walter H ..... 159

O

Old World prehistory, Recent progress in the field of (MacCurdy) ..... 495
Oliver, J ..... 34
Olmsted, Arthur J., photographer, National Museum ..... XII, 129
Organic evolution, The mechanism of (Davenport) ..... 417
Oropendola, Wagler's, The nesting habits of, on Barro Colorado Island (Chapman) ..... 347

P

Parent fund ..... 4
Parish, Lee ..... 35, 61
Parish, Mr. and Mrs. S. W ..... 35
Parmelee, James ..... 45
Pell fund, Cornelia Livingston ..... 150, 155
Penrose, Boies ..... 129
Perrygo, W. M ..... 35, 85
Philosophical Society of Washington ..... 128, 138
Physics, Modern concepts in, and their relation to chemistry (Langmuir) ..... 219

Page
Physics, modern, Waves and corpuscles in (De Broglie) 243
Pierce, Dr. W. Dwight 29
Pilsbry, Dr. H. A 35
Pinchot, Hon. Gifford 29, 35, 36, 85
Pitcairn, Harold F. (The autogiro: Its characteristics and accomplishments) 265
Plants, growth of, New researches on the effect of light waves on the (Brackett and Johnston) 255
Poole, Arthur J 13, 40
Poore fund, Lucy T. and George W 4, 150, 155
Post Office Department, United States 31
Postmaster General (member of the Institution) XI
Pratt, A. G 31
Prehistory, Old World, Recent progress in the field of (MacCurdy) 495
Prellwitz, Henry 48
President of the United States 2
Printing, allotments for 146
Printing and publication, Smithsonian advisory committee on 146
Public Buildings and Parks, Office of 40
Publications of the Institution and branches 13, 40, 52, 68
report 141

R

Radiation and Organisms, Division of 1, 11
cooperation 120
development of laboratory 116
initiation of experiments 117
library 126, 134
personnel 122
phototropic experiments 118
plant growth experiments 117
report 115
staff XII
summary 122
Radioactivity, The moon and (Forbes) 207
Rains, The first, and their geological significance (Hadding) 285
Ranger bequest, Henry Ward 18, 42, 47
exhibit 46, 48
fund 18
purchases 51
Rathbun, Miss Mary J 129
Ravenel, William de C., administrative assistant to the secretary XI, 129
Redfield, E. W 45
Redwood, Mrs. Frances T 31
Reeds, Chester A. (Weather and glaciation) 295
Regents of the Institution, Board of 2, 7, 18, 48
annual meeting, December 12, 1929 159
executive committee, report 149
meeting of February 13, 1930 160
permanent committee, report 160
proceedings of 159
special meeting of May 29, 1930 161

Page
Reid, E. D ... 37
Reid fund, Addision T ... 4, 150, 155
Reis, Doctor Heinrich ... 41
Research Corporation of New York ... 4, 12, 115, 161, 162
Resser, Dr. Charles E ... XII, 17, 30, 32, 38, 43
Revenue Cutter Service ... 32
Rhees fund ... 4
Rhoades, Katharine Nash, associate, Freer Gallery of Art ... XII
Richardson, Dr. Ernest Cushing ... 27, 123
Richarz, Stephen (The age of the human race in the light of geology) ... 451
Richmond, Dr. Charles W ... XII, 43, 129
Riley, J. R ... 129
Risting, Sigurd ... 129
Roberts, C. C ... 17, 28
Roberts, Dr. Frank H. H., jr ... XII, 19, 28, 61, 64, 65
John R. Swanton and (Jesse Walter Fewkes) ... 609
Robinson, Senator Joseph T. (regent) ... XI, 3, 159, 161
Rock, Dr. Joseph F ... 17, 28, 36
Roebling fund ... 4, 17, 29, 38, 150, 155
Roebling, John A ... 4, 161
Roosevelt, Theodore ... 24
Roosevelt, Theodore, jr ... 85
Rungius, Carl ... 48
Russell, James Townsend, jr ... 16, 31, 52, 128, 129, 133

S

St. John, Charles E. (Growth in our knowledge of the sun) ... 177
Sanche, Philip ... 66
Sanford fund ... 4
Schaus, Dr. William ... 4
Schmitt, Dr. Waldo L ... XII, 129
Schuchert, Charles (George Perkins Merrill (1854–1929)) ... 617
Science Service ... 104
Scott, Lloyd N ... 162
Searles, Stanley, editor, Bureau of American Ethnology ... XII, 145, 146
Seating furniture, ancient, in the collections of the United States National Museum (Hough) ... 511
Secretary of the Institution ... III, XII, 10, 13, 18, 24, 45, 48, 53, 71, 83, 102, 113, 114, 122, 125, 129, 140, 146, 159, 160, 161
Shakespeare Society ... 139
Shamel, H. H ... 37
Shoemaker, Coates W., chief clerk, International Exchanges ... XII, 83
Shu-Fan, Hon. Liu, Director General of Post of China ... 31
Simone, Edgardo ... 18
sculpture by ... 49
Small, Miss Angelica Frances ... 52
Smith, Albert C ... 37
Ellsworth P. Killip and (The use of fish poisons in South America) ... 401
Smith, Dr. Hugh M ... 17, 29, 36
Smith, John Donnell, botanical collection ... 132, 136
Smithson, James ... 2

Page
Smithsonian advisory committee on printing and publication ..... 146
annual reports ..... 14, 15, 141, 142
contributions to knowledge ..... 14, 141
endowment fund ..... 149
miscellaneous collections ..... 14, 141
Scientific Series ..... 2, 15, 159
James Smithson Memorial Edition of the ..... 1
List of Subscribers to the ..... 147
special publications ..... 141, 143
unrestricted fund ..... 4
Smithsonian-Parish expedition ..... 29
Smoke, John ..... 67
Smoot, Senator Reed (regent) ..... XI, 3, 160
Solórsano, Mrs. Ascensión ..... 63, 64
Sordahl, L. O ..... 113
Mrs ..... 113
Special exhibitions held in the [National] Gallery [of Art] ..... 48
Spectrum, Beyond the red in the (Babcock) ..... 165
Spinden, Dr. Herbert J ..... 42
Springer, Dr. Frank ..... 38
fund ..... 3, 4, 150, 155
Stanley, Miss Virginia ..... 117
State, Secretary of (member of Institution) ..... XI
Steamboat Inspection Service ..... 40
Stein, Sir Aurel ..... 59
Stejneger, Dr. Leonhard ..... XI, XII, 146
Stimson, Henry L., Secretary of State (member of the Institution) ..... XI
Stirling, Matthew W., chief, Bureau of American Ethnology ..... XII, 19, 71, 146
Stockwell, Sergt. R. A ..... 33, 68
Sturmer, J. W. (The modern sun cult) ..... 191
Sun cult, The modern (Sturmer) ..... 191
Sun, Growth in our knowledge of the (St. John) ..... 177
Swales, Bradshaw H ..... 29
Swales, Mrs. Mary R ..... 4
Swanson, Senator Claude A. (regent) ..... XI, 3, 159, 160
Swanton, Dr. John R ..... XII, 19, 61, 62
and F. H. H. Roberts, jr. (Jesse Walter Fewkes) ..... 609
Swingle, Doctor ..... 122
Széchenyi, Count László, minister from Hungary ..... 49

T

Taft, William Howard, Chief Justice of the United States (chancellor and member of the Institution) ..... 3, 21, 43, 159, 160, 161
Tarbell, E. C ..... 45
Tell en-Nasbeh excavations of 1929– a preliminary report, The (Badé) ..... 483
Thackery, Frank A., and M. French Gilman (A rare parasitic food plant of the Southwest) ..... 409
Thompson, Miss Eleanor ..... 60
Towner, Miss Isabel L ..... 44, 126
Traylor, James G., appointment clerk of the Institution ..... XII, 45

Page
Treasurer of the United States 156
Treasury, Secretary of the (member of the Institution) xi
True, Webster P., editor of the Institution xi, 31, 71, 146
Tucker, Miss Mae 71
Turkey, Government of 31

U

United Fruit Co 85

V

Vanderbilt, William K 129
Vice President of the United States (member and regent of the Institution) xi, 2, 3
Victorias Milling Co. of Manila 29
Visitors, National Museum 43

W

Walcott, Dr. Charles D 9
Mrs. Charles D 129
fund, Charles D. and Mary Vaux 3, 4, 150, 155
Walker, Ernest P., assistant director, National Zoological Park xii, 84
(Wild life protection—an urgent problem) 327
War Department, United States 68
War, Secretary of (member of the Institution) xi
Ward, Robert De C. (The acclimatization of the white race in the Tropics) 557
Warmbath, Julian S 44
Warner, Miss May 50
Warner, Mrs. Worcester Reed 17, 29
Washington Federation of Churches 49
Washington Manuscripts 135
Waves and corpuscles in modern physics (De Broglie) 243
Weather Bureau, United States 104, 138
Weather and glaciation (Reeds) 295
Weniger, Doctor 120
Wenley, Mr 60
Wetmore, Dr. Alexander, assistant secretary of the Institution xi, 13, 36, 44, 129, 159, 160
Wheeler, Ralph 85
Wheeler, William Morton 23
Whistler, James McNeill 135
White, Dr. David xii, 30
White race in the Tropics, The acclimatization of the (Ward) 557
Wilbur, Ray Lyman, Secretary of the Interior (member of the Institution) xi, 42
Wild life protection—an urgent problem (Walker) 327
Wilkens, Hans 4
Wimsatt, Miss Genevieve B 50
Wissler, Dr. Clark 42
Wistar Institute cards 138
Woodin, Miss Gertrude L 44, 127
Wright, Orville 7
Wright, Wilbur 7

## Y

Page
Yaeger, William L. 158
Yale University 138
Younger fund, Helen Walcott 3, 4, 150, 155

## Z

Zodtner, H. H. 113
Zoological Park, National 1, 7, 20
accessions 84
animals in the collection June 30, 1930 90
director XII, 102, 146
donors (list of) 85
improvements 100
needs of the zoo 101
removals 89
report 84
staff XII
visitors 99
Zoological Society of London 137

O